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**Model MD-35**  
**VASCULAR DIAGNOSTIC SYSTEM**

**MANUAL**

**Serial Number**\_\_\_\_\_

## MD-35 Procord

|                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Introduction</b>         | Hokanson <b>MD-35 Procord</b> contains three diagnostic instruments in one convenient, portable package. The MD-35 contains a direction-sensing continuous wave Doppler, an infrared photo plethysmograph, and a pneumo plethysmograph. Since several types of diagnostic tests can be performed with more than one of the instruments contained in the MD-35, the user may choose the most appropriate one for the particular case at hand. A two speed chart recorder in the MD-35 can record the volume information from two plethysmographs or the velocity information from the Doppler.                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>LED Bar Graph</b>        | An LED bar graph indicator shows the amplitude and position of the signal corresponding to the chart recorder. The starting position (baseline) can be moved to any place on the chart with the position control. The LED bar graph is helpful in setting the controls prior to starting the chart recorder by indicating the size and location where the signal will appear on the chart recorder.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Doppler Unit</b>         | The Doppler unit contained in the MD-35 is a 5 MHz continuous wave instrument with a bifocal lens on its transducer which makes it useful for both deep and shallow blood vessels. The Doppler audio output is related to blood flow in the region of the ultrasonic beam of the transducer. The amplitude of the audio output is proportional to the volume of flowing blood, while the frequency or pitch of the signal is proportional to the velocity of the blood relative to the angle of the sound beam. In addition to the loudspeaker output, the Doppler audio is processed in a zero-crossing frequency to voltage converter for recording on the internal chart recorder. Sensitivity of the chart recorder is from 10 Hz to 10 KHz per centimeter of chart deflection. Typically the range used during recording will be from 0.20 KHz/cm to 2 KHz/cm. The recorder and bar graph show direction and velocity of flow relative to the transducer by deflection above and below the base (zero flow) line position. |
| <b>General Description</b>  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Photo Plethysmograph</b> | The photo plethysmograph employs a pair of infrared emitters and detectors. Blood in the skin and superficial tissue reflects the infrared and the output of the photo plethysmograph is proportional to the amount of blood in this tissue. Although the absolute amplitude of the output cannot be calibrated to indicate pulse volume, the photo plethysmograph is still useful as a pulse detector in measuring blood pressure in the extremities and in producing waveforms which can be analyzed for shape and comparative amplitude between similar sites on opposite sides of the body.                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>General Description</b>  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

**Pneumo  
Plethysmograph**

**General  
Description**

Pneumo Plethysmography is also known as volume pulse recording and pulse volume recording. It is possible to calibrate the pneumo plethysmograph by injecting and withdrawing a known volume of air from the sensing cuff with a syringe, however this is infrequently done. Note that calibration in this way indicates the total volume change in the volume under the sensing cuff. The size of the waveforms obtained with the pneumo plethysmograph depends on the size of the cuff and the volume and pressure of air in the sensing cuff. Thus, if calibration is not used, it is important to use the same size cuffs applied in the same way when comparative measurements are to be made. Good waveforms can generally be obtained using the pneumo plethysmograph and it is useful for qualitative waveforms and as an end point detector for taking blood pressure in the extremities.

**Specifications**

**Doppler**

|                 |                                             |
|-----------------|---------------------------------------------|
| Ultrasonic      |                                             |
| Frequency       | 5.185 MHz                                   |
| Useful Range    | 5 cm                                        |
| Audio Bandwidth | 300 to 15,000 Hz                            |
| Noise Reduction | DNR (National Semiconductor)                |
| Power Output    | 85 m W/cm                                   |
| Signal to Noise | Typically 40:1 or more for a carotid artery |

**Photo**

**Plethysmograph**

|             |                                                                                                         |
|-------------|---------------------------------------------------------------------------------------------------------|
| Sensitivity | Dual Infrared transmitters and receivers typically can detect a pulsatile waveform on any body surface. |
|-------------|---------------------------------------------------------------------------------------------------------|

**Pneumo**

**Plethysmograph**

|             |                                                                                        |
|-------------|----------------------------------------------------------------------------------------|
| Cuff Type   | All cuff sizes may be used as a sensing cuff. Connector is a female Luer lock fitting. |
| Sensitivity | 0.1 mm Hg pressure change equals 1 cm chart deflection on the most sensitive scale.    |

**ART(AC) VEIN(DC)**

Selectable coupling in plethysmograph modes. Time constant of AC coupling is 0.15 seconds. Frequency response: DC-DC to 28 Hz, AC- 1 to 28 Hz.

**Display**

20 segment LED bar graph shows signal corresponding to chart recorder

**Chart Recorder**

|             |                                                 |
|-------------|-------------------------------------------------|
| Chart Paper | 4 cm wide grid on 5 cm wide thermal chart paper |
|-------------|-------------------------------------------------|

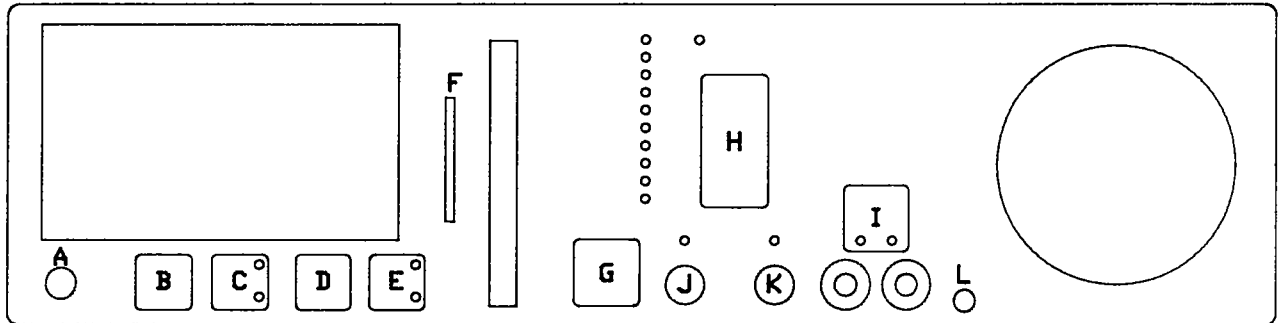
|        |                                   |
|--------|-----------------------------------|
| Speeds | Slow = 5 mm/sec, Fast = 25 mm/sec |
|--------|-----------------------------------|

**Electrical**

120 VAC 60 Hz  
Japanese and European voltage models available.

### **Physical**

|        |                     |
|--------|---------------------|
| Weight | 8.0 lbs., 3.64 kgs. |
| Height | 4.75 in., 11 cm     |
| Width  | 15.125 in., 38.5 cm |
| Depth  | 11.375 in., 29 cm   |



### **MD-35 Front Panel**

#### **Operating Instructions**

Location and operation of external controls, connectors and indicators.

- |                       |                                                                                                                                                                                                                                                                                                                                                                                                      |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>A. Power</b>       | Push button switch: Push in to turn on. Push and release to turn off.                                                                                                                                                                                                                                                                                                                                |
| <b>B. Run Stop</b>    | Alternate action push button to start and stop the chart recorder. This duplicates the action of the push-button on the Doppler probe                                                                                                                                                                                                                                                                |
| <b>C. Speed</b>       | Push button to set chart recorder speed. Slow is 5 mm/sec, Fast is 25 mm/sec.                                                                                                                                                                                                                                                                                                                        |
| <b>D. Zero</b>        | Push-button to balance the plethysmographs. This offsets any baseline shift, so small changes can be amplified even though they have a large baseline offset. Pushing this switch also gives a zero flow signal in the Doppler mode to show the baseline level.                                                                                                                                      |
| <b>E. Artery/Vein</b> | <p>Push button to select coupling of output for plethysmographic modes. In Doppler mode the instrument is always DC coupled because the zero flow level for the Doppler has no offset.</p> <p>Use ARterial (AC) coupling when the baseline level is not desired and only pulsatile information is wanted. Use VEIN (DC) coupling for venous exams when long term baseline changes are important.</p> |
| <b>F. Position</b>    | Slide control for neutral position of the baseline on the chart recorder and the bar graph.                                                                                                                                                                                                                                                                                                          |
| <b>G. Select</b>      | Push button to control the mode of operation.                                                                                                                                                                                                                                                                                                                                                        |

|                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>H. Range</b>                     | <p>Two push-buttons select the gain or sensitivity of the output signal on the chart recorder and bar graph. Sensitivity for the Doppler is from 10 KHz to 0.01 KHz (10 Hz) per cm on the chart.</p> <p>Typical ranges for use will be from 2 to 0.2 KHz for the Doppler. The pneumo plethysmograph can only be calibrated by injecting a known volume of air in the sensing cuff so in practice this is seldom done. Also, calibration for the photo plethysmograph is not meaningful. In all cases the Range Control sets the size of the output signal on the recorder.</p> |
| <b>I. Pneumo</b>                    | <p>One of the lights on this switch will light whenever Pneumo mode is selected. Pushing the switch will toggle between RECOrd and INFLate mode. In INFLate mode the cuff connected to the blue port can be inflated by an inflator connected to the black port. In RECOrd mode the cuff is sealed and the inflator may be removed for use on another cuff.</p>                                                                                                                                                                                                                |
| <b>J. Doppler</b>                   | <p>Connector for the Doppler transducer. The small black button on the top of the connector must be depressed in order to disconnect the transducer. The light above the connector lights to indicate Doppler mode.</p>                                                                                                                                                                                                                                                                                                                                                        |
| <b>K. Photo</b>                     | <p>Connector for the infrared photo transducer. The small black button on top of the connector must be depressed in order to remove the photo transducer. Do not pull on the cable to remove the plug. The light above the connector lights up to indicate photo plethysmograph mode.</p>                                                                                                                                                                                                                                                                                      |
| <b>L. Phones</b>                    | <p>This is a miniature phone jack for stereo headphones. Both sides of the jack are wired to the same signal. There is no stereo effect.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>M. Doppler Controls</b>          | <p><b>Controls on the Doppler probe</b> include the volume control thumbwheel, the push-button on the back of the probe to start and stop the chart recorder, and the toggle switch to invert the waveform on the chart.</p>                                                                                                                                                                                                                                                                                                                                                   |
| <b>N. Serial Data Out</b>           | <p>A rear panel jack for the optional computer interface. This signal is an electrically isolated, serial digital interface available for connecting the output to a computer. This jack is only connected on units equipped with the optional RS-232 serial interface. When using the MD-35 with a computer it is <b>important not to make any electrical connection to the computer other than through the RS-232 cable so as not to defeat the electrical isolation of the instrument.</b></p>                                                                              |
| <b>O. Computer - Chart Recorder</b> | <p>A rear panel switch for selecting recorder or computer (RS232) mode. In the <b>Chart Recorder</b> position the chart recorder operates normally. In the <b>Computer</b> position the chart recorder control will not start the chart recorder, but instead starts or stops the data trace on a computer connected to the instrument. A ¼" phone jack below this switch allows a remote switch to perform the same function so the MD35 can be used in a rack.</p>                                                                                                           |

## Pneumo Plethysmography

### General Description

The pneumo plethysmograph records volume changes in a limb or digit by measuring the pressure change in a recording cuff which is applied at low pressure. This type of plethysmograph is also called a pulse volume recorder or a volume pulse recorder. It is possible to calibrate the pneumo plethysmograph by injecting a known volume of air into the cuff and noting the amount of deflection this causes on the chart recorder. Usually the instruments are used in an uncalibrated manner to show waveforms and to detect volume pulsations. Various sizes of cuffs may be used depending on the part of the body being measured. The instrument is easy to use and gives clean volume pulse waveforms for very small volume changes. Tests that can be performed with this instrument include volume pulse recordings, maximum venous outflow (MVO), and blood pressure.

### Operation

Select **Pneumo** mode on the MD-35 Procord and apply the recording cuff snugly to the area of interest. Using the plastic hose with a blue male Luer lock connector on each end, connect the cuff to the blue **Cuff** port on the MD-35. Connect a cuff inflator or sphygmomanometer to the black **Inflate** port on the MD-35. Pushing the **Pneumo** button toggles the mode from **Inflate** to **Record**. In **Record** mode the recording cuff is connected directly to the cuff, the **Inflate** port is sealed, and the inflator may be removed for use in inflating a separate pressure cuff.

In **Inflate** mode, inflate the recording cuff to the desired pressure - usually 15 to 60 mm Hg. Push the **Pneumo** button to switch to **Record** mode. Balance the instrument by momentarily depressing the Zero button. Set the Range to the desired sensitivity, select **Artery** or **Vein** mode and start the chart recorder.

### Digit Pressures

Apply a digit cuff as a sensing cuff to the distal part to the digit to be measured. Apply another digit cuff proximal to the first, to be used as the pressure cuff. Inflate the sensing cuff to approximately 60 mm Hg and then move the cuff inflator to the pressure cuff. Set the sensitivity to the 0.02 range. Inflate the pressure cuff to a pressure above the expected systolic pressure level. Balance the instrument by pressing the **Zero** button and start the recorder running on slow. The baseline of the recording should be flat if the pressure cuff is occluding the arteries in the digit. Slowly lower the pressure in the occluding pressure cuff. Set the sensitivity to the 0.02 range. Inflate the pressure cuff to a pressure above the expected systolic pressure level. Balance the instrument by pressing the **Zero** button and start the recorder running on slow. The baseline of the

recording should be flat if the pressure cuff is occluding the arteries in the digit. Slowly lower the pressure in the occluding cuff and watch the baseline of the recorder for a sudden rise. If the recording is made in **Vein** (DC) mode the first blood to flow under the cuff will cause the volume of the digit to increase in a stepwise fashion. Note the pressure of the pressure cuff at the first steps, this is the systolic pressure. The recording may also be done in **Arterial** (AC) mode. In this case the reappearance of pulses as the cuff pressure is lowered indicates the return of flow.

### Arterial Waveforms

Arterial waveforms may be recorded from digits and limbs by applying appropriate size cuffs to those areas. As explained above, the waveforms can be calibrated, but in typical applications they aren't. Set the mode to **Arterial** (AC) mode and inflate the sensing cuff to 60 mm Hg. Press the **Zero** button and start the chart running at **Slow** speed. Adjust the **Range** and **Position** controls for an appropriate size pulse on the chart recorder. Run the recorder at **Fast** speed for 3 or 4 waveforms.

The above paragraph describes the way this test is normally carried out. It is also possible to do the test in **Vein** (DC) mode which actually will give a more accurate waveform. In order to do this, repeat the above steps with the instrument in **Vein** (DC) mode. The reason this makes more accurate waveforms is that in **Arterial** (AC) mode the signal passes through a high pass filter which causes some distortion of the waveform. The advantage and reason for using **Arterial** mode is that this allows the recording of rapid (pulsatile) waveforms independent of the baseline changes that occur with respiration.



VEIN, DC COUPLED

ARTERIAL, AC COUPLED

### ARTERIAL VOLUME PULSE RECORDING

Interpretation of the waveforms is based on shape and size. Normal waveforms have a sharp rise and a dicrotic notch. Please refer to the references for more information.

## Maximum Venous Outflow

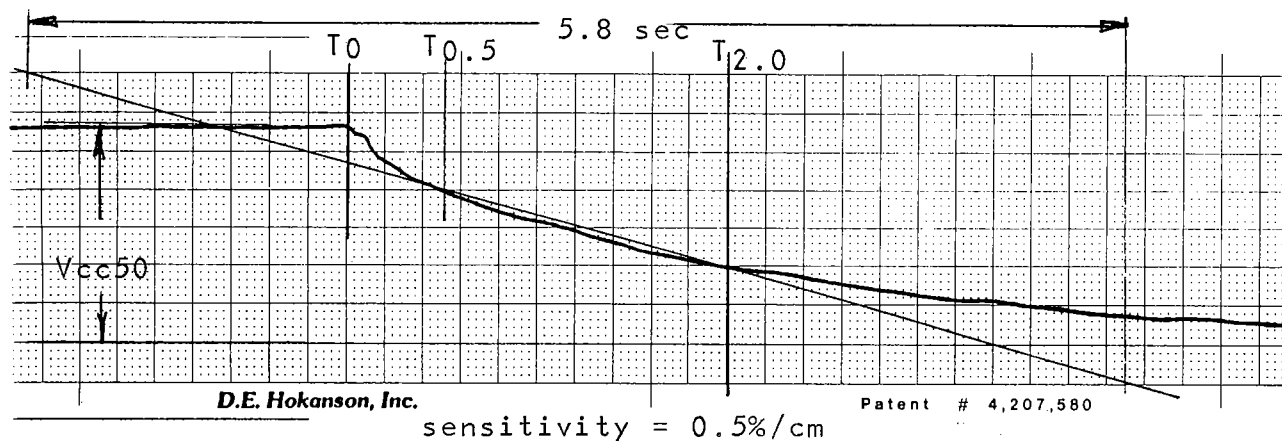
The description of the maximum venous outflow tests contained in the paper by Cramer, et al, at the rear of this manual can also be applied to a pneumo plethysmograph by substituting a sensing cuff for the strain gauge.

Position the patient supine, rotate the legs and prop up the heels so that the feet are 27 cm above the bed. Please refer to figure 1 in Cramer's paper. Apply an SC-10 or SC-12 recording cuff to the widest part of the calf. Apply a CC-17 or CC-22 contoured thigh cuff to the thigh and connect it to an RD-2 Rapid Cuff Deflator. Put the MD-35 into **Vein** mode, select **Pneumo Inflate** and inflate the recording cuff to 20 mm Hg. Select the **Pneumo Record** mode and disconnect the inflator from the MD-35 and connect it to the venous occluding cuff on the thigh in preparation for inflating it. Balance the MD-35 by momentarily pushing the **Zero** button. Start the recorder running at **Slow** (5 mm/sec) and adjust the baseline to 5 mm (one small box) above the baseline.

Set the sensitivity to 2.0 with the **Range** controls and inflate the thigh cuff to a pressure of 50 mm Hg for a period of 45 seconds. Notice the amount of volume change on the recorder and adjust the **Range** setting if necessary so that the recorder shows much less than a full scale deflection in the 45 second period. The ideal sensitivity is one that gives a nearly full scale deflection in the two minute venous occlusion period which follows. Deflate the thigh cuff and repeat the 45 second inflation. These two trial inflations tend to seat the thigh cuff and stretch the veins so that the MVO will be less dependent on venous tone.

Rebalance the MD-35, start the recorder running at 5 mm/sec, and reset the baseline prior to the final measurement. Inflate the thigh cuff once more to 50 mm Hg and leave it inflated for a period of two minutes. It is not necessary to run the chart recorder for the entire two minutes. After the baseline recording is made the recorder may be stopped until you are ready to perform the outflow test. The volume increase of the calf during this period is called the **venous capacitance** at 50 mm Hg. It is important to note the pressure at which venous capacitance measurements are made since this affects it. After the two minute period, start the recorder running **Fast** (25 mm/sec) and deflate the thigh cuff rapidly with the RD-2 Rapid Cuff Deflator. Stop the recorder when the recording has returned to the baseline level. If the recording falls below the original baseline this indicates that the recording cuff has moved or that it has lost some air since the instrument was last balanced; if this happens, check for air leaks in the recording cuff and repeat the test.

Interpretation of the MVO can be made by plotting the venous capacitance versus venous outflow on the graph shown at the end of this manual. Even though the pneumo plethysmograph has not been calibrated, the chart can be used because it is showing a ratio between inflow and outflow recordings which were made on the same sensitivity range.



## Venous Outflow Recording

The example above shows the MVO curve. The baseline prior to 2 minutes of cuff inflation was 5 mm above the bottom of the chart. The cuff was deflated at  $T_0$ . Venous capacitance,  $V_{cc50}$ , is the volume change from the baseline to the final volume achieved after 2 minutes. In the example, this is  $2.8 \text{ cm} \times 0.5\%/\text{cm} = 1.4\%$ . This value would be plotted on the vertical axis of the MVO chart. The outflow in the interval from 0.5 to 2.0 seconds,  $VO_{.5-2}$ , is measured in the example by drawing a line across the chart, through the  $T_{0.5}$  and  $T_{2.0}$  points on the MVO curve. This line crosses the chart in 5.8 seconds so the outflow rate is 2% (the volume change across the chart is  $4 \text{ cm} \times 0.5\%/\text{cm}$ ) in 5.8 seconds. This translates into  $2\% \times 60 \text{ sec}/\text{min} / 5.8 \text{ sec} = 20.7\%/\text{min}$ . Plotting this as the horizontal point on the MVO chart with the 1.4% measured for  $V_{cc50}$  gives a point well above the discriminant line and therefore indicates this is a normal study. The same values could be measured by applying the clear overlay to the example.

### Venous Reflux

Venous reflux is retrograde flow of blood in the veins. Normally competent valves in the veins prevent reflux. Incompetent valves give rise to higher than normal venous pressure when a person stands and this can cause pain and swelling of the legs.

The degree of reflux and the origin of it (whether in the deep or superficial venous system) can be measured by placing a sensing cuff (20 mm Hg) around the calf. A tourniquet cuff applied to the upper thigh is inflated to supersystolic pressure and a large contoured thigh cuff is applied to the thigh just below the tourniquet. The large contoured cuff is inflated as rapidly as possible to a pressure of 50 mm Hg. This added pressure on the sealed leg attempts to drive blood back down the leg. The amount of increase in volume of the leg is then a measure of the venous reflux. Normal values for this test will be less than 2% volume increase. When the test is done with an uncalibrated pneumo plethysmograph, the 2% volume increase can be estimated by doing a venous capacitance test as listed above under Maximum Venous Outflow.

In order to determine if the reflux is due to the superficial veins the test can be performed with an additional tourniquet applied just below the knee which is just tight enough to prevent reflux in the superficial veins. A smaller blood pressure cuff, such as the Hokanson SC-5 which has a 5 x 40 cm bladder, is ideal for use as the knee cuff because it allows a measured pressure to be applied to the superficial veins. Usually a pressure of 40 to 50 mm Hg is used for this cuff.

## Photo Plethysmography

### Photo Transducer Application

The photo plethysmograph in the MD-35 measures the reflection of infrared light from the skin and subcutaneous tissue. Infrared light is emitted by light emitting diodes in the photo transducer and its reflection is sensed by photo detectors which are adjacent to them. The photo detectors are also sensitive to visible light so it is important to apply the transducer snugly to the skin. The transducer can be applied with clear, double-backed adhesive tape to any flat surface. On digits or limbs it can also be applied by taping or strapping around the body. In the latter case care should be taken not to apply it so tightly that the skin is exsanguinated. It is also a good idea to tape the lead wire from the transducer to the skin at a point close to the transducer so that movement of the lead wire will not move the transducer on the skin.

Plug the photo transducer into the MD-35 and select **Photo** mode. Select **Arterial** or **Vein** coupling and the appropriate **Range** setting and then depress the **Zero** switch momentarily. Start the chart recorder to record the signal.

### Digit Pulse Waveforms

Apply the photo transducer to the fleshy pad on the tip of the finger or toe. Balance the plethysmograph and select a sensitivity **Range** which will give reasonably large pulses on the chart recorder. Two modes of recording are possible with the MD-35 plethysmograph. **Vein** (DC) coupling shows long and short term changes while **Arterial** (AC) coupling only shows the more rapid pulse changes. In **Vein** mode long term volume changes caused by respiration or limb elevation will move the baseline of the recording. **Arterial** mode constantly restores the baseline. Using **Arterial** mode is common for digit waveform recording because it is easier to keep the plethysmograph balanced and still have adequate size waveforms on the recorder.

Digit pulse waveforms are useful in diagnosing arterial obstruction and cold sensitivity. **Thoracic outlet syndrome** may be diagnosed by placing a photo transducer on a finger and then observing the disappearance of the pulse as the patient moves his arm and performs various maneuvers. For this test the plethysmograph should be **Arterial** coupled to the chart recorder so that the overall volume changes caused by elevating the arm do not drive the tracing off scale.

## Blood Pressure

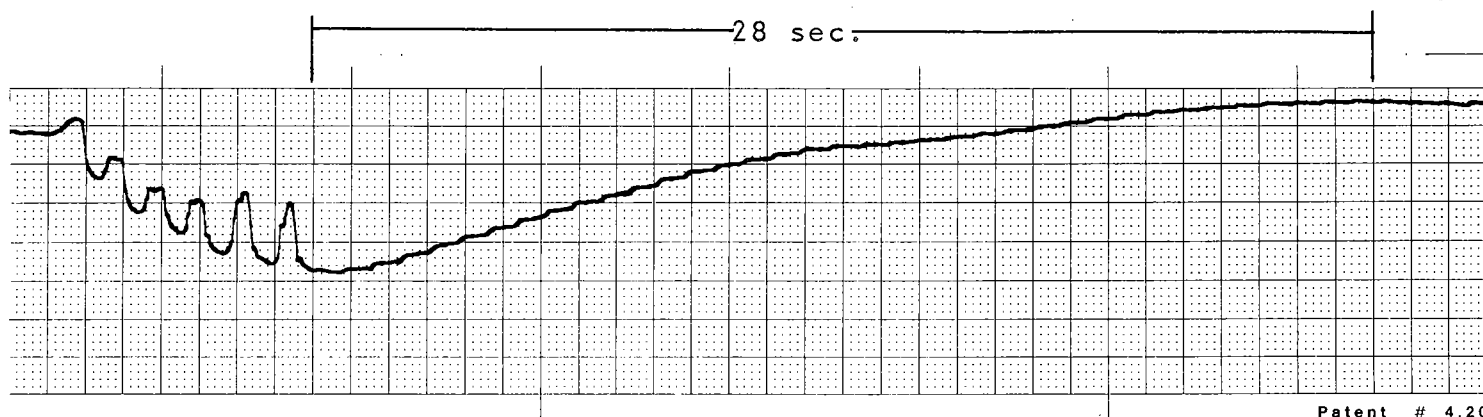
For blood pressure measurements with a photo plethysmograph the transducer is applied to an extremity distal to the cuff and the return of flow indicates the systolic pressure. If the plethysmograph is used in Vein mode it will be easier to see the first increase in volume that occurs with the return of blood flow.

## Venous Reflux

Venous reflux or insufficiency can be measured with a photo plethysmograph by applying the transducer above the medial malleolus or on the medial aspect of the calf just below the popliteal fossa. The veins of the calf are emptied by one of several means. The refilling time of the veins, as measured by the photo plethysmograph, is indicative of venous reflux. In the abnormal case the veins will refill faster because of flow back past the venous valves, while normal refilling occurs only by arterial flow through the muscles.

Various methods of emptying the calf veins are by tipping up on the toes while standing, foot flexion while sitting with the legs dependent, manual compression, and compression by a cuff. Generally about 5 rapid compression maneuvers are performed which empty the veins in a series of steps. The refilling occurs as soon as the patient is allowed to relax. If all goes well the chart recording will return, with perhaps a small overshoot, to the original baseline.

Measure the time from the minimum volume reached after the last maneuver to the point where the volume curve either (1) starts to flatten and stays flat for 5 seconds or (2) reverses and begins to fall. If this time is greater than 25 seconds the response is considered to be normal. A time of less than 20 seconds indicates abnormal venous reflux.



Patent # 4,20

## Venous Reflux Test

### **Supraorbital Plethysmography**

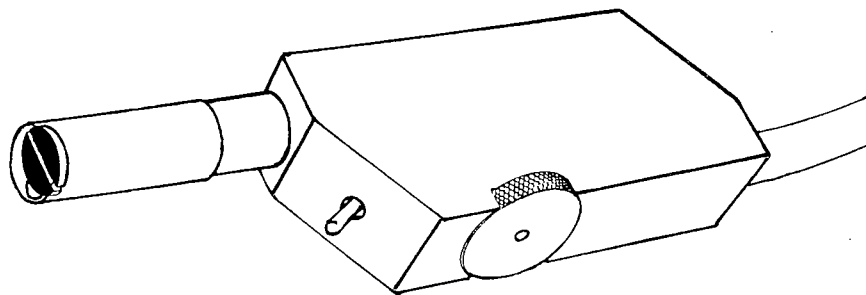
Photo plethysmography has been used to detect obstructions of the internal carotid artery by sensing altered ophthalmic artery flow. Two plethysmographs can be used for this test. One transducer is placed on each side of the patient's forehead over the supraorbital region. Sequentially, bilateral compression maneuvers are performed on branches of the external carotid artery followed by compression of each common carotid artery. Variations in the symmetrical waveforms during the bilateral compression maneuvers is abnormal as is the failure of a waveform to change when the ipsilateral common carotid is compressed.

### **Doppler**

The MD-35 contains a direction-sensing, 5 MHz, continuous wave Doppler which is useful for most peripheral vascular exams. Controls on the probe allow the user to start and stop the chart recorder, change the audio volume, and invert the Doppler waveform on the chart recorder. The chart recorder start/stop button can even be used as a remote switch when the instrument is being used in plethysmographic modes. Direction of blood flow is shown on the bar graph and chart recorder with flow in one direction indicated above the baseline and the other below. The Doppler transducer has a unique, patented bifocal lens which allows it to be used for both deep and shallow blood vessels.

### **Coupling Gel**

Coupling of ultrasound from the probe to the tissue is greatly improved by the use of an ultrasonic coupling gel such as Ultraphonic conductivity gel.. Whenever the Doppler signal seems weak, check that there is good contact from the probe to the skin by means of coupling gel.



**Doppler Transducer Showing Orientation of Piezoelectric Elements**

|                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Doppler Transducer</b>            | The transmitting and receiving elements of the Doppler transducer are aligned vertically in the face of the probe. The raised area on the surface of the probe is the near focus lens which improves the performance of the instrument for shallow vessels. Hold the Doppler probe so that both the transmitting and receiving crystal make contact with the skin. If the subject vessel is shallow, rotate the transducer so that the near focus lens (bump) is adjacent to the skin. On the other hand, if the vessel is more than 1 cm from the surface, better results will be obtained by rotating the transducer 180° so that the near focus lens is away from the skin. |
| <b>Care of Transducer</b>            | The tip of the transducer is delicate because it is very sensitive. It is a good idea to wipe off the tip and keep the red protective cap on the transducer when it is not in use.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Positioning the Doppler Probe</b> | When searching for a Doppler signal, move the transducer very slowly over the region where flow is expected. If the movement is too rapid it is possible to pass over the vessel between heartbeats without finding it. In using a Doppler it is important to realize that <b>an acute angle is necessary</b> between the Doppler probe and the blood vessel to be measured. The frequency of the signal received by the instrument changes when blood flows toward or away from the probe, however, <b>no Doppler change will exist when the probe is pointed perpendicular to a blood vessel.</b>                                                                            |
| <b>Flow Direction</b>                | The direction of flow will be indicated by the bar graph and chart recorder. This can be demonstrated by alternately pointing the transducer upstream and downstream over an artery and observing the bar graph indicator. The zero level of the recording can be recorded as a baseline by pressing the <b>Zero</b> switch. If the flow signal is upside down, it can be inverted by switching the small toggle switch on the front of the probe.                                                                                                                                                                                                                             |
| <b>Doppler Calibration</b>           | Calibration of the Doppler signal is in terms of KHz/cm on the chart as indicated by the Range lights. The Doppler frequency is dependent on the angle $\theta$ between the ultrasound beam and the blood vessel. The instantaneous mean of the blood velocity is related to the frequency by the formula $\Delta f = (2V \cos \theta f_0)/u$ . For this Doppler the transmitting frequency, $f_0$ is 5.185 MHz and the speed of sound in tissue may be taken to be 154,000 cm/sec so this formula reduces to $\Delta f = 67.3V \cos \theta$ Hz. The following table shows the relation of velocity to frequency:                                                              |

**Table of Frequency versus Velocity for specific angles**

| Frequency          | Angle | 30°   | 45°   | 60°   |
|--------------------|-------|-------|-------|-------|
| 500 Hz             |       | 8.6   | 10.5  | 14.9  |
| 1000 Hz            |       | 17.2  | 21.0  | 29.7  |
| 2000 Hz            |       | 34.3  | 42.0  | 59.4  |
| 3000 Hz            |       | 51.4  | 63.0  | 89.1  |
| 4000 Hz            |       | 68.6  | 84.0  | 118.8 |
| 5000 Hz            |       | 85.7  | 105.0 | 148.5 |
| 6000 Hz            |       | 102.9 | 126.0 | 178.2 |
| Velocity in cm/sec |       |       |       |       |

**Interpretation of Doppler**

The Doppler is a very versatile instrument which is invaluable to the physician and technologist in the assessment of vascular function. Patterns of sound are as important as the degree of frequency shifts. Practice and experience are required to get the most out of the Doppler. Several institutions offer excellent short courses in vascular laboratory techniques including the use of the Doppler. One excellent self-teaching guide in the use of Dopplers is offered by the University of Iowa Audiovisual Center, Iowa City, IA 52242. This course comes with programmed texts and taped cassettes of Doppler sounds for use in the diagnoses of venous disease, peripheral vascular disease, and cerebrovascular disease.

**Loading the Chart Recorder**

To load chart paper into the recorder, pull on the black tabs that protrude from the right side of the recorder and swing them out. If necessary, remove the core of the previous roll of chart paper by pulling on the clear plastic tape behind the roll to dislodge it. Unroll enough of a new roll of chart paper (Hokanson, heat sensitive chart paper, 4 cm x 100 foot chart) so that the words along the bottom of the chart can be seen. Orient the roll with the words right side up along the bottom edge and push it into the cavity of the recorder. Pull out about 6 inches of paper and close the recorder. **Do not attempt to thread the paper under the bar on the edge of the platen.** Run the recorder at fast speed and insert the loose end of the chart under the right side of the rollers on the left side of the recorder. Run a few inches of paper to allow the chart to straighten out before stopping the recorder.

**Service**

There are no user serviceable parts in the MD-35. The cover should never be removed except by qualified service personnel. Tampering with the instrument during the warranty period will void the warranty.

**References for Further Reading**

1. Quantitative Segmental Pulse Volume Recorder: A Clinical Tool, by R. Clement Darling, MD, et al, in Surgery, Vol. 72, No. 6, Dec. 1972, pp. 873-867.

2. Noninvasive Diagnostic Techniques in Vascular Disease 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> editions, Edited by Eugene F. Bernstein, MD, Published by C. V. Mosby Co., St. Louis, MO 1978 - 1985.
3. Practical Noninvasive Vascular Diagnosis, Edited by Richard F. Kempczinski, MD, and James S. T. Yao, MD, Published by Year Book Medical Publishers Inc., Chicago, IL 1982.
4. A Guide to Survival for a New Noninvasive Vascular Lab, by Claudia Beal Rumwell, RN, Published by Kroma International Graphics Inc., Spokane, WA 1982.
5. Noninvasive Diagnosis of Vascular Disease, Edited by Falls B. Hershey, MD, Robert W. Barnes, MD, and David S. Sumner, MD, Published by Appleton Davies Inc., Pasadena, CA 1984.

## **GUARANTEE**

The MD-35 PROCORD is guaranteed against defects in parts, workmanship, and performance for a period of five years from the date of delivery provided that the instrument is not abused or repaired by an unauthorized person. Repair is free of charge when the instrument is returned prepaid. Return shipment will be made at our expense in a manner similar to your shipment to us. Transducers, blood pressure cuffs and accessories are guaranteed for one year. Batteries and headphones are excluded.

Please call the factory at 1(800)999-8251 before sending any instrument for repair.

# The Detection of Proximal Deep Vein Thrombosis by Strain Gauge Plethysmography Through the Use of An Outflow/Capacitance Discriminant Line\*

Miles Cramer, B.S.,\*\* K.W. Beach, Ph.D., M.D.,\*\* D.E. Strandness, Jr., M.D.\*\*

**ABSTRACT** The accurate detection of thrombi in the deep veins of the lower extremities (DVT) by non-invasive techniques remains one of the most challenging tasks of the vascular laboratory. Venous flow may be quantified by strain gauge plethysmography (SPG), but the reported measurements have been highly variable. Such variability may be eliminated by correlating the rate of venous outflow (VO) to venous capacitance (VC), thereby normalizing the flow characteristics for any given leg. Also, using a VO/VC ratio allows laboratories employing SPG to compare results.

This study was designed to test the ability of the VO/VC discriminant line to detect proximal DVT and to determine the length of time past the onset of symptoms that the correlation would still hold true.

Forty-five patients (22 female, 23 male) with histories of proximal DVT were studied by SPG for time periods ranging from 3 days to 312 weeks past the event. All patients were verified by venography and were categorized into 3 groups, depending on the length of time between the DVT and the date of examination: acute  $\leq 1$  week, early = 1-4 weeks, and late  $> 1$  month. The VO/VC ratio maintained a sensitivity of 100% and a specificity of 92% for the acute group. Past one week, however, the sensitivity and specificity fell to 75% and 94% respectively for the early group, and 17% and 93% respectively for the late group.

Consequently, proximal DVT may be accurately detected by SPG through the use of a VO/VC ratio, provided the examination is performed within one week of the thrombotic event.

## Introduction

Plethysmographic techniques are widely being used to assess the patency of deep veins in the proximal lower extremities (above the popliteal fossa). The accuracy of many plethysmographs has been reported to range from 85% to 92% with Phleboreography (PRG) and Impedance Plethysmography (IPG) generally assumed to be the most accurate.<sup>1</sup> Strain Gauge Plethysmography (SPG), one of the most widely used and reliable methods of quantifying extremity blood flow, has occasionally been maligned as being less accurate than either PRG or IPG in detecting acute deep vein thrombosis (DVT). This confusion stems from variations in equipment design, examination protocol, and data analysis. Recently, however, it has been shown that such variation can be eliminated by standardizing the study protocol and by utilizing a venous outflow/venous capacitance ratio as the diagnostic criterion.<sup>2</sup> Consequently, an SPG discriminant line has

been proposed which will accurately separate normal legs from those affected by acute DVT.

## Materials and Methods

Forty-five patients (22 female, 23 male) with venographically proven proximal DVT were studied by SPG for time periods ranging from 3 days to 312 weeks past the date of the event. The age range for females was 17 to 67 years (mean = 34.4) and for males 17 to 76 years (mean = 47.4). The subjects were categorized into 3 groups depending on the length of time between the DVT and the date of their first examination: acute  $\leq 1$  week ( $n = 12$ ), early = 1-4 weeks ( $n = 16$ ), and late  $> 1$  month ( $n = 45$ ). There were 29 cases where the left leg was affected (19 female, 10 male) and 16 cases which involved the right leg (3 female, 13 male).

Two commercially available SPG systems were used to measure venous flow parameters. The Hokanson system\* is an electrically calibrated plethysmograph which utilizes a 4-wire lead, double-looped strain gauge. The gauge is mercury filled and designed to encircle the calf exactly once. The Medimatic system\*\* is also an electrically calibrated plethysmograph that employs a 2-wire lead mercury filled strain gauge. This gauge was designed to

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be either underlapped or overlapped around the calf and is applied so that the gap or overlap is located equally across the tibia. This was done to standardize capacitance and outflow values since the calf does not expand uniformly during venous occlusion. The greatest circumferential increase occurs in the posterior compartment containing the gastrocnemius muscle.<sup>3</sup> In all cases rapid cuff deflation systems with large bore (17 mm I.D.) outflow tubing were used to pressurize and de-pressurize the venous occlusion thigh cuffs.

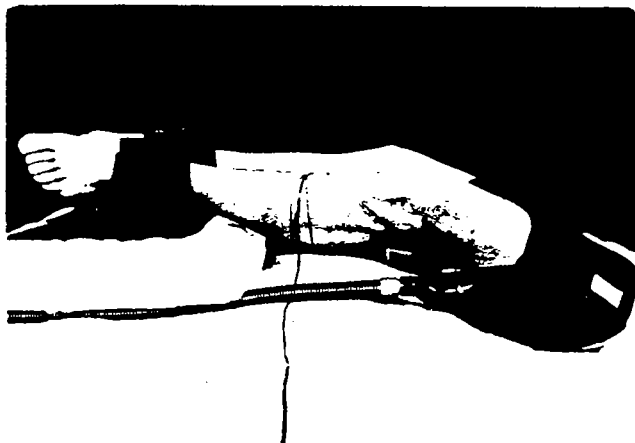


Figure 1.

The legs are positioned 27 cm above the back. The calves should not touch the bed.

The patients were positioned supine with both feet evenly elevated 27 cm above the level of the patient's back (Figure 1). The height of leg elevation above heart level has been shown to be of major importance in maximizing venous flow measurements, thereby improving one's ability to differentiate those legs harboring proximal outflow obstruction.<sup>4</sup> Both legs were slightly abducted and externally rotated with mild knee flexion to reduce the chance of outflow restriction resulting from extrinsic compression of the popliteal vein at the fossa. The thighs were supported by foam wedges as were the feet. One strain gauge was placed around each calf at its maximum circumference and a venous occlusion cuff (14 cm x 27 cm) was placed around each proximal thigh. The patient was instructed on the importance of muscle relaxation during the testing period.

To begin measurement, the chart recorder was started at 0.3 mm/sec followed by the activation of a calibration marker (Figure 2). This marker represents a 1% change in the electrical resistance of the conductor inside the gauge which is equal to a 1% change in limb volume or a 0.5% change in gauge length. The thigh cuff was first inflated on the presumed normal leg to a pressure of 55 mmHg

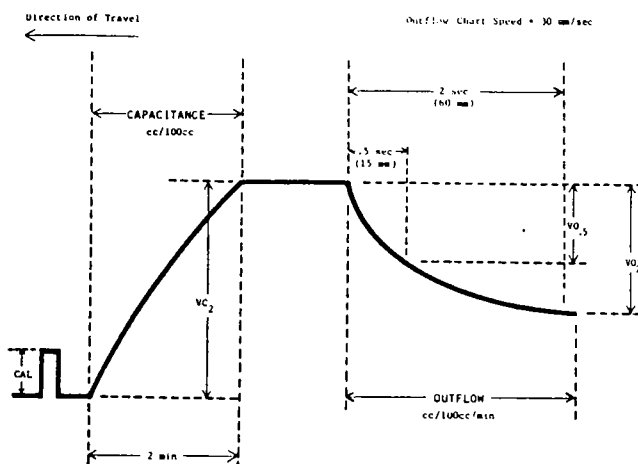


Figure 2.

Diagram of venous capacitance and outflow curve. Specific measurement locations are shown.

which was sufficient to occlude both the deep and superficial veins beneath the cuff. During this time, veins distal to the occlusion cuff were filling with blood and venous capacitance (VC) was being measured. Two minutes after occlusion, a time marker was activated to identify VC<sub>2</sub> and the chart speed was increased to 30 mm/sec. Quickly, the thigh cuff was deflated permitting the release of blood from the engorged veins, yielding the measurement of venous outflow (VO). This series was repeated twice on each leg, alternately. A minimum number of tests were performed due to the remote possibility of a thrombus being dislodged by continual compression and release of the occlusion cuff resulting in a potentially fatal pulmonary embolus (PE). No complications have ever been reported, but the danger still exists.<sup>5</sup>

The outflow and capacitance curves can be divided into several time intervals (Figure 2). This method is preferred to the tangent line method of calculating "maximum venous outflow" due to the high degree of intraobserver variability encountered in estimating the correct angle of the tangent line to the outflow curve. One of the most accurate methods of evaluating the outflow curve involves measuring a segment spanning 0.5 to 2 seconds after the release of the venous occlusion cuff.<sup>2</sup> The most important reason for beginning measurement 0.5 seconds after the onset of VO is to avoid measurement error. Those patients who had developed an extensive collateral bed following a femoral vein DVT will have these collaterals compressed during venous occlusion. Consequently, the rush of high pressure venous blood into such a collateral bed upon release of the occlusion cuff may be great enough to equal or even exceed the rate of flow which would normally have existed in the major deep vessels. One would be less likely to encounter falsely elevated outflow values by looking later in the outflow curve where the venous flow is more likely to be under the influence of normal hemodynamic parameters such as gravity. Further, the

\*Model EC-4, D.E. Hokanson, Inc., Issaquah, Washington.

\*\*Medimatic, Division of M.I.D., Hellerup, Denmark.

analysis of a segment of the curve is more apt to give an accurate picture of the venous flow characteristics than by looking at just one point. Eliminating that section of the curve from 0 to 0.5 seconds will help reduce false-negative errors.

**CALCULATIONS:** Venous capacitance after 2 minutes of thigh compression ( $VC_2$ ) was calculated by measuring the distance in mm from the baseline to the maximum height of the curve and dividing this distance by the height of the calibration mark ( $CAL = 1\% \Delta V$ ). The resulting number may be referred to as percent increase, or volume in cc blood/100 cc tissue. For example, if the height of CAL was 10 mm and the height of the capacitance curve was 15 mm, the resultant  $VC_2$  would be  $15 \text{ mm} \div 10 \text{ mm} = 1.5\%$  increase in leg volume or 1.5 cc/100 cc tissue. Similarly, to calculate  $VO$  at 0.5 ( $VO_{.5}$ ) and 2 ( $VO_2$ ) seconds after cuff deflation, one should measure the respective excursions of the curve from the baseline at both time periods and divide each by CAL. In each case the resultant number, a volume, may be converted into a rate of flow in cc/100 cc/min by introducing a "time normalizing factor." For example, the venous outflow rates at 0.5 and 2 seconds, assuming excursions from the baseline of 7 mm and 15 mm respectively with a CAL of 10 mm, would be:

$$VO_{.5} = \frac{7 \text{ mm}}{10 \text{ mm}} \times 120 = 84 \text{ cc/100 cc/min}^*$$

$$VO_2 = \frac{15 \text{ mm}}{10 \text{ mm}} \times 30 = 45 \text{ cc/100 cc/min}^{**}$$

The outflow interval between 0.5 and 2 seconds would be calculated by the equation:

$$VO_{.5-2} = (4/3) VO_2 - (1/3) VO_{.5}$$

This segment of the outflow curve has been found to have the highest correlation with  $VC_2$  than any single outflow value ( $p < .001$ ).<sup>2</sup>

Using the values from the above example,  $VO_{.5} = 84 \text{ cc/100 cc/min}$  and  $VO_2 = 45 \text{ cc/100 cc/min}$ , the outflow interval  $VO_{.5-2}$  would be:

$$(4/3) 45 - (1/3) 84 = 60 - 28 \text{ or } VO_{.5-2} = 32 \text{ cc/100 cc/min}$$

## Results

Empirically, when the  $VO_{.5-2}/VC_2$  values of acutely diseased legs were plotted against the same ratio for a normal population,<sup>2</sup> a discriminant line was developed which distinctly separated the two groups (Figure 3). Only 2% of the normals fell below the line into the abnormal zone. By adjusting the line to a more convenient scale and plotting the diseased against the contra-lateral (assumed normal) legs for the 12 patients with acute DVT, there is very good separation yielding a sensitivity of 100% and specificity of 92% (Figure 4). The single false-positive value was the contra-lateral leg of a patient who had bilateral DVT. A radionuclide venogram revealed a left ilio-femoral occlusion with

suspected abnormal filling in the right calf. This type of venogram is not able to accurately detect disease below the popliteal fossa. However, if there had been thrombosis of the tibial and the distal popliteal vein, the  $VO/VC$  results may have accurately detected significant right leg disease.

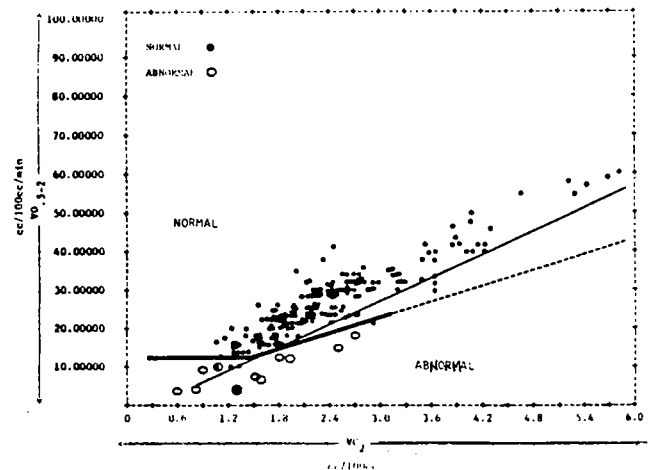


Figure 3.

$VO_{.5-2}/VC_2$  discriminant line separates acutely diseased legs from a normal population. The thin line represents the lower 95% confidence limits of the normal group.

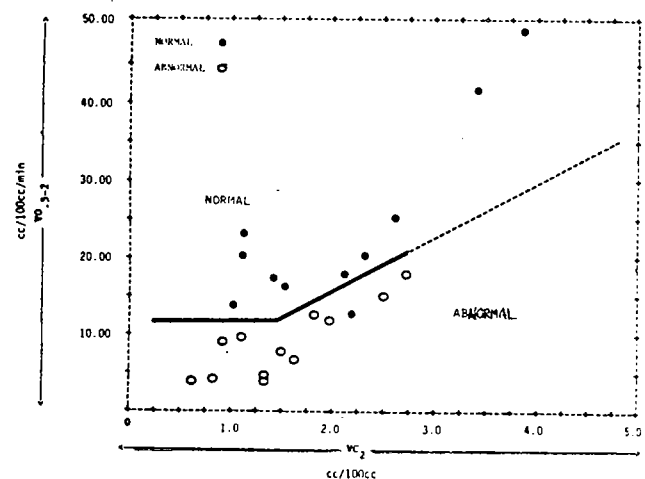


Figure 4.

The discriminant line accurately separates the abnormal from the contra-lateral legs of 12 patients in the acute group ( $\leq 1$  week).

The sensitivity and specificity for the early group fell to 75% and 94% respectively (Figure 5), while the late group values gave a sensitivity of 17% and a specificity of 93% (Figure 6).

The range of values for  $VO_{.5}$ ,  $VO_2$ ,  $VO_{.5-2}$ , and  $VC_2$  in abnormal and contralateral legs for the 3 groups is listed in Table I. In all cases, the mean values for

\*  $120 \times 0.5 = 60$  seconds

\*\*  $30 \times 2 = 60$  seconds

diseased legs were lower than those of normal legs. There was, however, considerable overlap between normal and abnormal leg values when the range within each group was compared. In all cases, the flow parameters became progressively larger as patients migrated from acute to early to late categories.

A frequency plot of the SPG values  $VO_{5-2}/VC_2$  clearly demonstrates the movement of diseased legs into the normal zone over the 3 time periods (Figure 7). Note that there is a trend for the values to parallel the discriminant line as they move toward the normal zone. Generally, when venous outflow increases, so does capacitance.

## Discussion

The ability of a  $VO/VC$  discriminant line to detect DVT has been well documented by those who use plethysmographic techniques other than SPG.<sup>6,8</sup> Venous flow data from any two strain gauge plethysmographs may be accurately compared providing the outflow measurements are normalized to the capacitance measurements for each system.<sup>2</sup> The variability of "maximum venous outflow" measurements is far too great to enable one to use this single parameter alone for accurate data comparison.

Accurate detection of lower extremity venous occlusion by plethysmography requires the consideration of more obscure and sometimes complex hemodynamic changes in the venous system such as collateral flow. The location and extent of occlusion, post-thrombotic ambulation, coagulation anomalies, anatomical irregularities, pregnancy, and other factors must all contribute to the development of venous collaterals. It is clear that the venous system attempts to rapidly regain homeostasis following DVT, but the precise length of time for stabilization remains variable.

It is of interest to note that 13 of the 22 female patients (59%) developed a DVT in connection with either hormone therapy or childbirth: hormone therapy = 5 (22.7%), post c-section surgery = 3 (13.6%), post-partum = 5 (22.7%). Women had nearly twice as many left leg DVT's as did men. Anatomically, the right iliac artery crosses over the left iliac vein, predisposing both sexes to a higher incidence of left leg DVT. For women, however, additional compression of the iliac vein by a large uterus during pregnancy coupled with systemic hormonal changes probably accounts for such a high incidence of left leg DVT.

By looking at an interval later in the outflow curve one can be more secure that those flow values are a reflection of the true status of the deep venous system and are not as likely to be falsely elevated by rapid collateral filling. While the sensitivity of 100% (based upon the acute group in the study) may fall slightly as more individuals are examined, SPG has proven to be at least as accurate as other currently employed plethysmographic techniques. Any vascular laboratory using SPG to detect acute DVT will be able to utilize the same  $VO/VC$  discriminant line if:

- 1) the occlusion occurs in or proximal to the popliteal vein,
- 2) the plethysmographic exam occurs within one week of the thrombosis,
- 3) the outflow interval  $VO_{5-2}$  is plotted against venous capacitance at 2 minutes,
- 4) standardized protocol for SPG examination are followed.

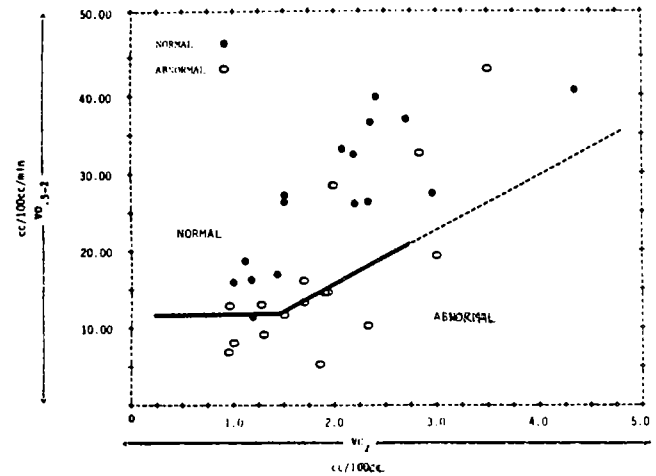


Figure 5.

The sensitivity and specificity for the early group (1-4 weeks) fell to 75% and 94% respectively.

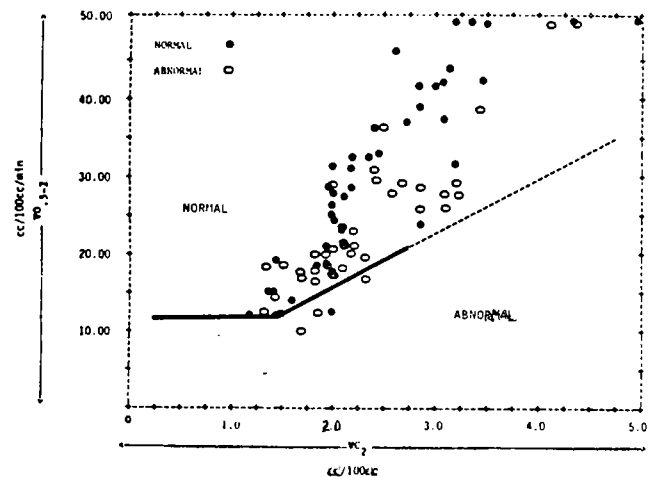
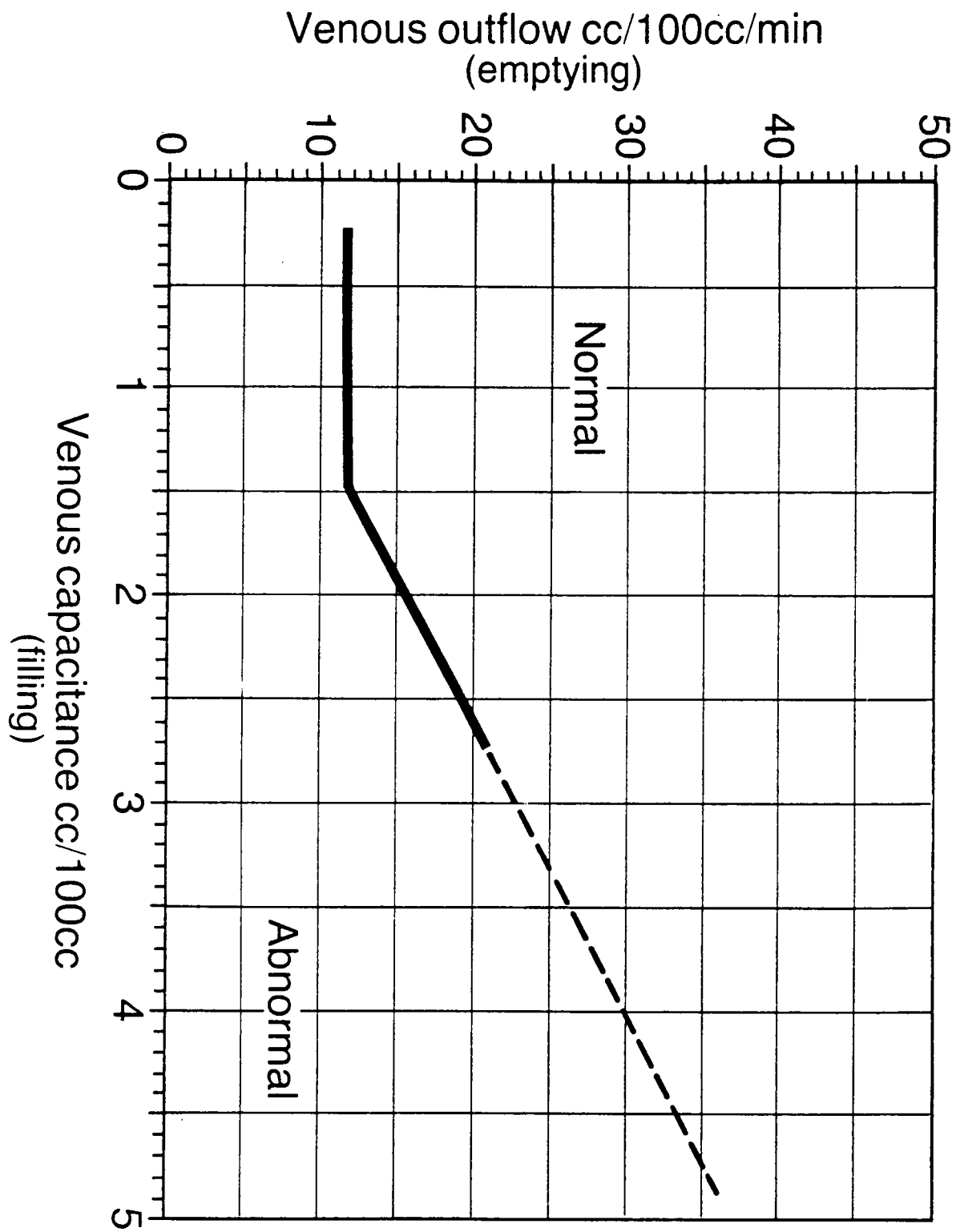


Figure 6.

The late group (>1 month) displayed a sensitivity of only 17% and a specificity of 93%.

The authors wish to thank Joyce Nakamura for manuscript preparation.



|           | AVO <sub>5</sub> | NVO <sub>5</sub> | AVO <sub>2</sub> | NVO <sub>2</sub> | AVO <sub>5-2</sub> | NVO <sub>5-2</sub> | AVC <sub>2</sub> | NVC <sub>2</sub> |
|-----------|------------------|------------------|------------------|------------------|--------------------|--------------------|------------------|------------------|
|           | 8.9-41.7         | 17.6-108.5       | 5.1-23.0         | 16.2-72.1        | 3.9-18.4           | 12.9-59.9          | 0.6-2.7          | 1.0-4.3          |
| ACUTE     | 23.6             | 48.3             | 12.7 +           | 30.7             | 9.1 +              | 24.9               | 1.5              | 2.1              |
| ≤ 1 week  | ±3.5             | ±8.5             | ±1.8             | ±5.0             | ±1.4               | ±4.3               | ±0.2             | ±0.3             |
|           | 11.7-72.7        | 9.3-87.2         | 8.3-50.7         | 10.4-52.2        | 4.8-43.3           | 10.7-40.5          | 0.9-3.5          | 1.0-4.3          |
| EARLY     | 31.3             | 47.6             | 19.3             | 31.9             | 15.3 +             | 26.7               | 1.8              | 2.1              |
| 1-4 weeks | ±4.6             | ±5.4             | ±3.0             | ±2.9             | ±2.6               | ±2.3               | ±0.2             | ±0.2             |
|           | 17.2-111.4       | 17.6-141.2       | 12.7-72.4        | 13.5-79.2        | 10.1-59.5          | 11.9-66.8          | 1.3-4.3          | 1.2-5.2          |
| LATE      | 41.9 +           | 55.7             | 27.9             | 37.7             | 23.2 +             | 31.7               | 2.3              | 2.5              |
| > 4 weeks | ±3.0             | ±3.9             | ±2.0             | ±2.5             | ±1.6               | ±2.1               | ±0.1             | ±0.1             |

+  $p < .001$

Table I

Numerical display of the range, mean  $\pm$  S.E.M., and statistical significance ( $p < .001$ ). N = Normal; A = Abnormal.

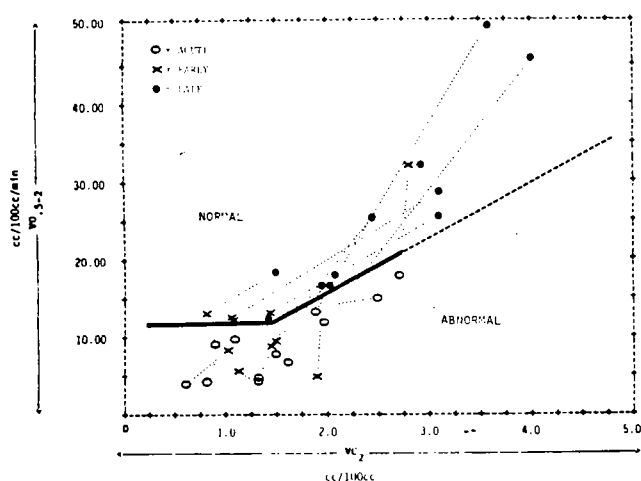


Figure 7.

A frequency plot of 12 patients shows the migration of the diseased legs into the normal zone for the 3 time periods.

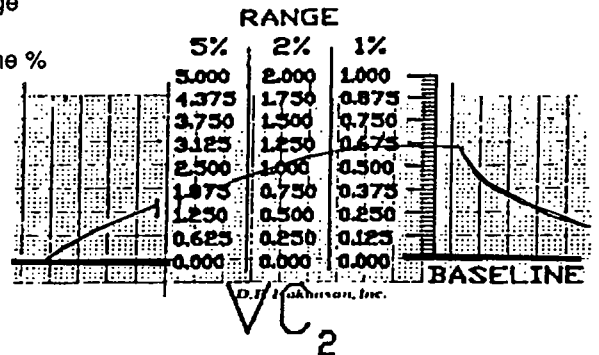
## References

- <sup>1</sup>Barnes, RW: Diagnosis of deep venous thrombosis, part 2. Accuracy, advantages, and limitations, and clinical applications of techniques. *VD & T* 2: 38-42, Dec/Jan, 1981.
- <sup>2</sup>Cramer, M, Langlois, Y, Beach, K, Martin, D and Strandness, DE, Jr: Standardization of venous flow measurement by strain gauge plethysmography in normal subjects. *Bruit VII*: 33-39, March, 1983.
- <sup>3</sup>Knox, R, Cramer, M, Beach, K, Fell, G, Breslau, P and Strandness, DE, Jr: Pitfall of venous occlusion plethysmography. *Angiology* 33(4): 268-276, 1982.
- <sup>4</sup>Tripolitis, AJ, Blackshear, W, Bodily, K, Thiele, B and Strandness, DE, Jr: The influence of limb elevation, examination technique, and outflow systems on venous plethysmography. *Angiology* 31(3): 154-163, 1980.
- <sup>5</sup>Wheeler, HB and Anderson, FA, Jr: Impedance plethysmography. In Kempczinski, R, Yao, JST (eds.): *Practical Vascular Diagnosis*, Chicago, Yearbook Medical Publishers, p. 277-303, 1982.
- <sup>6</sup>Hull, R, Van Aken, WG, Hirsch, J, Gallus, AS, Haika, G, Turpia, AGG, Walker, I and Gent, M: Impedance plethysmography using occlusive cuff technique in the diagnosis of venous thrombosis. *Circulation* 53: 696-700, 1976.
- <sup>7</sup>Wheeler, HB and Anderson, FA, Jr: Impedance plethysmography: the diagnosis of venous thrombosis by occlusive impedance plethysmography. In Bernstein, FF (ed.): *Non-invasive Diagnostic Techniques in Vascular Disease*, 2nd ed., St. Louis, CV Mosby Co., p. 482, 1982.
- <sup>8</sup>Wheeler, HB, Patwardhan, NA and Anderson, FA, Jr: In Bergan, JJ and Yao, JST (eds.): *Vascular Problems*, Chicago, Yearbook Medical Publishers, Inc., Chapter 10, 1978.

# INSTRUCTIONS FOR USING OVERLAY

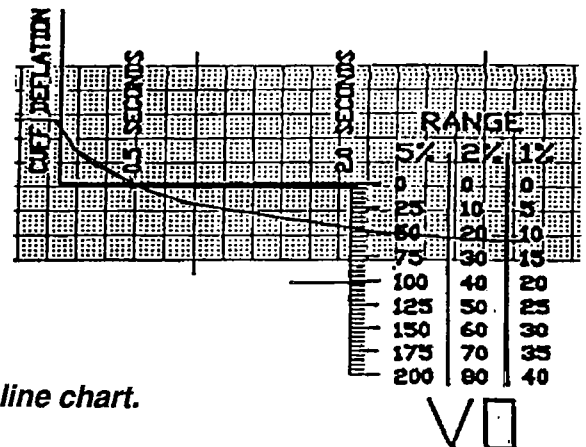
## VENOUS CAPACITANCE ( $VC_2$ )

- Align the chart recording so the pre-inflation baseline matches "Baseline" on the overlay.
- Note the range setting on the plethysmograph and select the proper range column from the overlay.
- Determine the VC from the plateau line on the chart recording, reading the % volume change from the correct column on the overlay.



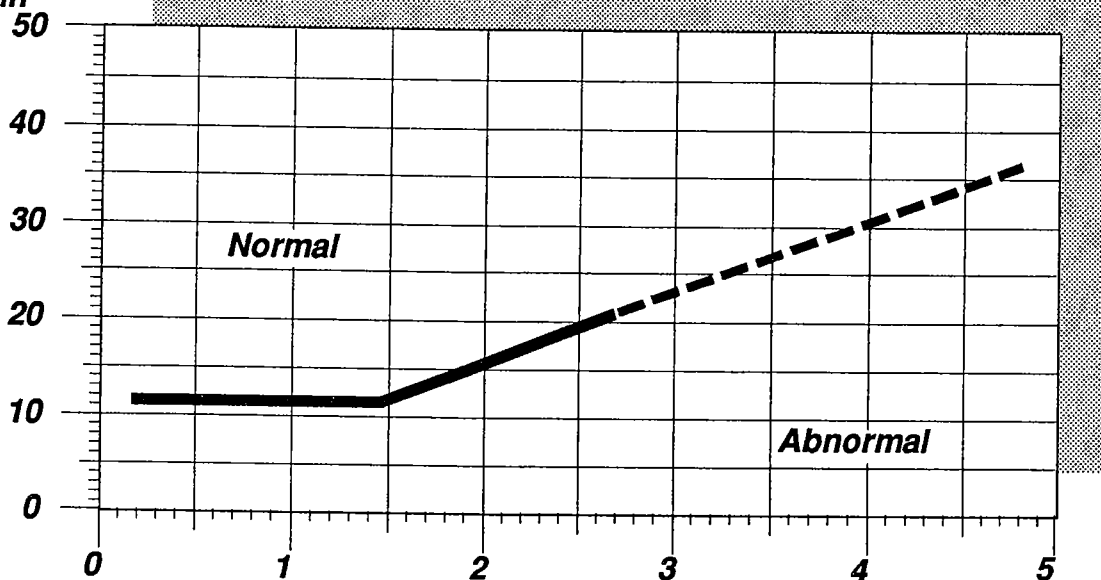
## VENOUS OUTFLOW (VO)

- Align the overlay so the "CUFF DEFLATION" line matches the first declination point on the outflow curve on the chart recording.
- Slide the overlay down so the "0.5 SECOND" ----- intersects the outflow curve.
- Read the outflow from the overlay where the curve intersects the "2.0 SECOND" line, using the same range value setting as in the  $VC_2$  calculation.



Plot the values for  $VC_2$  and  $VO_{(.5-2)}$  on the discriminant line chart.

Venous outflow  
cc/100cc/min



Venous capacitance cc/100 cc

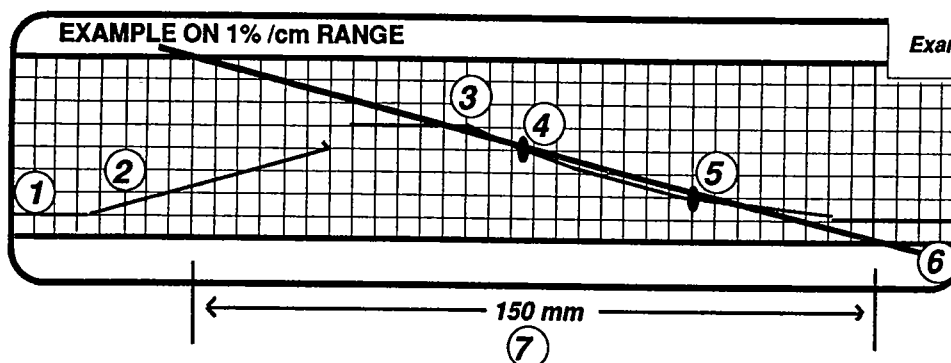
Baseline resting state of leg at 5 mm/sec. ①  
 Cuff inflation applied. ②  
 After 2 minutes, chart recorder speed is increased to 25 mm/sec. Cuff pressure is quickly released and pressure returns to baseline. ③  
 Since in 1 second the graph travels 25 mm, the reference point of .5 seconds is 12.5 mm from the point of rapid deflation. ④  
 The 2 second reference is 50 mm from the rapid deflation point. ⑤  
 Slope line is drawn through .5 and 2 second reference points, all the way to the end of the graph paper. ⑥  
 Determine the time (millimeters) where the line crosses the graph paper above and below. ⑦

## MEASUREMENTS AND CALCULATIONS (not using overlay)

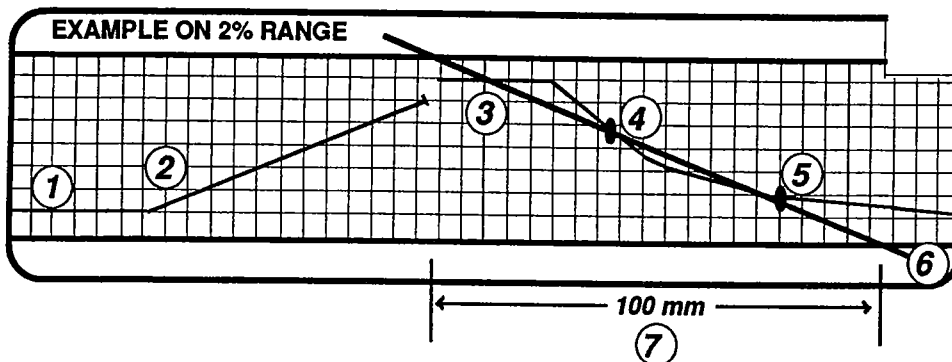
### OUTFLOW (VO)

Time of line is figured:

Example for units that use percent per centimeter



$$\begin{aligned} & \frac{150 \text{ mm}}{25 \text{ mm}} \quad (\text{in this example}) \\ & \quad \text{Speed of chart recorder} \\ & \quad = T (\text{Time}) = 6 \text{ seconds} \\ & \frac{60 \text{ sec}}{T (6 \text{ sec})} \times \text{Unit Range times } 4 = 40 \%/\text{min} \end{aligned}$$



Example for units that use full scale (EC-4)

$$\begin{aligned} & \frac{100 \text{ mm}}{25 \text{ mm}} \quad (\text{in this example}) \\ & \quad \text{Speed of chart recorder} \\ & \quad = T (\text{Time}) = 4 \text{ seconds} \\ & \frac{60 \text{ sec}}{T (4 \text{ sec})} \times 2 (\text{EC-4 Range at } 2\%) = 30 \%/\text{min} \end{aligned}$$

### CAPACITANCE (VC)

Example for units that use percent per centimeter

Count number of mm from original baseline up to 2 minute inflation line. In this example, since the range is on the 1%/cm setting, then 1 cm up represents 1%. So the total capacitance in this case = 2 %

Example for units that use full scale (EC-4)

Count number of mm from original baseline up to 2 minute inflation line. In this example, since the total rise has incorporated 30 out of 40 millimeters (6/8 of chart capacity) the calculation is as follows:

$$\frac{30}{40} \text{ times } 2 (\text{EC-4 range}) = 1.5 \%$$

**Plot VO & VC on discriminant line chart** (on previous page). Points that fall below the line are suspect of acute or early deep vein thrombosis. Points that fall above the line represent normal studies. Care must be taken in interpreting these values to note the time from the onset of symptoms to the time of the test, as the development of collateral veins can mask a deep obstruction.

#### References

Strandness, D. E. Jr, and David Sumner, "Hemodynamics for Surgeons" C.V. Mosby St. Louis 1975.  
 Cramer, Miles; D.W. Beach and D. E. Strandness, Jr, "The Detection of Proximal Deep Venous Thrombosis by Strain Gauge Plethysmography through the use of an Outflow/Capacitance Discriminant line" Brult December 1983.

# DEEP VENOUS THROMBOSIS

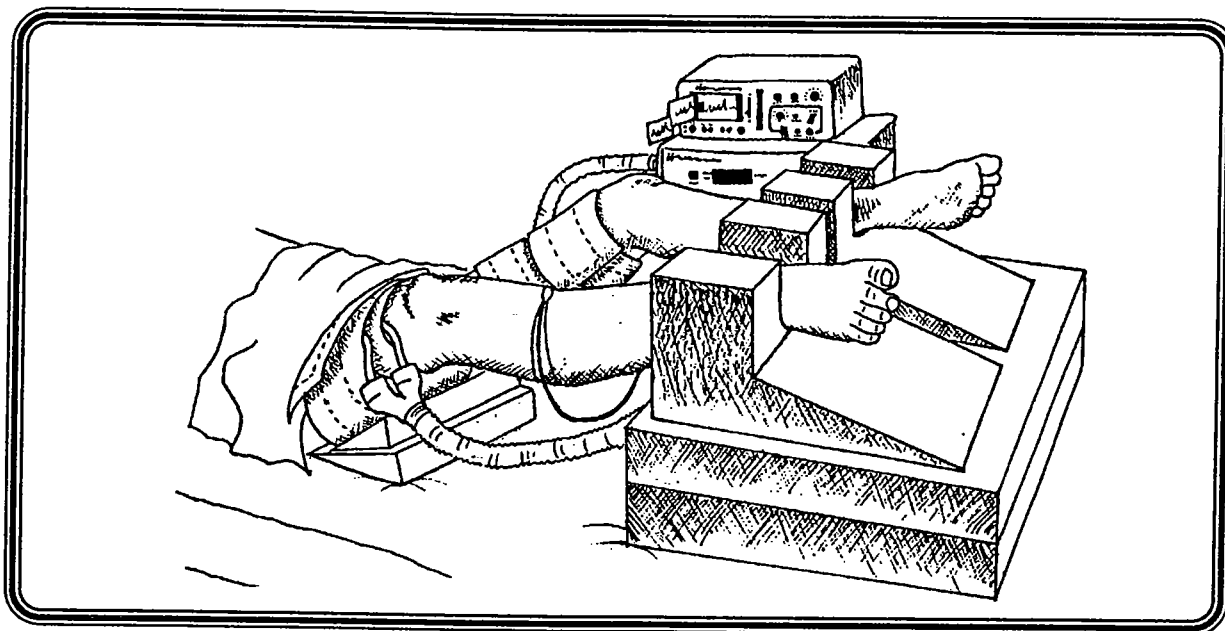
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Acute and early deep venous thrombosis (DVT) can be accurately diagnosed by strain gauge plethysmography or pneumo plethysmography. Although the strain gauge plethysmograph is able to measure absolute volume changes, the diagnosis is generally made by comparing venous capacitance to venous outflow. When both capacitance and outflow are measured with the same instrument at the same sensitivity, the calibration of the plethysmograph drops out of the analysis. The results can be plotted on a chart with the normals and abnormals separated by a discriminant line.

Inflating a large contoured thigh cuff to super-venous pressure causes venous outflow to cease. The calf veins will expand and volume of the calf increases until venous pressure reaches the cuff pressure. The amount of expansion (venous capacitance or VC) depends on the cuff pressure. Typically, with a cuff pressure of 50 mm Hg, equilibrium will be reached in about 2 minutes. The increased volume measured by the plethysmograph is the Venous Capacitance.

Rapid deflation of the contoured thigh allows a large bolus of blood to flow out and places the deep venous system under maximum load. The rate of decrease in volume of the calf is the Venous Outflow (VO) rate.

Like all tests, this one must be done carefully! Accurate, reproducible results are only possible by strict adherence to established procedures.

## Limitations:

This procedure is unable to differentiate intrinsic obstruction from external compression.

### Sources of false positives:

- \*Poor positioning
- \*Obesity
- \*Pregnancy (the problems with obesity and pregnancy can frequently be alleviated by having the patient turn on their side in a lateral decubitus position and then do the test on the leg that is up)
- \*Poor cardiac output
- \*Congestive heart failure
- \*Arterial occlusive disease
- \*Shock/vasoconstriction

## TECHNIQUE

### Strain Gauge or Pneumo Plethysmography

1. Before beginning the examination, have the patient rest supine on the bed or table for 10 to 15 minutes.
2. Elevate the legs 27 cm above the level of the patient's back, using foam wedges to support the hips and thighs, and foam blocks to position the legs and feet. Bend the leg slightly at the hip and knee, and rotate it outward.
3. Apply a large contoured cuff around the proximal thigh, alternately tightening each tail to ensure a snug fit.

**STRAIN GAUGE PLETHYSMOGRAPHY:** Measure the circumference of the widest part of the calf and select a strain gauge 2 or 3 cm smaller. Apply the gauge so that the junction is positioned next to the tibia (not on the sharp edge of the bone) and secure this portion of the gauge by taping it to the skin. Connect the gauge to the plethysmograph, select an appropriate range (at least 2% full scale) and balance the plethysmograph tracing near the bottom of the graph on the chart recorder. Use the DC mode on the plethysmograph for this test.

**PNEUMO PLETHYSMOGRAPHY:** Attach an SC-10 cuff to the calf and attach the pneumo hose to the plethysmograph. Inflate the SC-10 sensing cuff to 25 mmHg, and select an appropriate scale during the 45 second preliminary inflations so that full scale expansion in 2 minutes will nearly fill the chart recording (A typical scale might be 0.5). Use VEIN (DC) mode on the plethysmograph.

4. Connect the thigh cuff to a rapid deflation device. In order to decrease venous tone and maximize capacitance, inflate the cuff to 50 mmHg for 45 seconds, then deflate and allow a 2 minute rest/drain period. Do this at least twice before the first actual measurement.
5. To begin the measurement, start the chart recorder running on Slow and re-balance the tracing to the bottom of the graph (If your plethysmograph has a cal switch, you may mark a 1% volume change on the chart paper).
6. Inflate the thigh cuff to 50 mmHg to occlude venous return from the leg. The limb volume will increase due to arterial inflow and will reach a plateau after about 2 minutes. This plateau represents the VC at 50 mm Hg. (Note: It is not necessary to run the chart recorder the full two minutes. The meter or L.E.D. bar graph on the plethysmograph will monitor the VC).
7. Two minutes after inflating the thigh cuff, increase the chart speed to 25 mm/sec and rapidly deflate the cuff. The downward curve shows the venous outflow.

# PLETHYSMOGRAPHIC DETECTION OF BLOOD PRESSURE

**Hokanson**

A.N. FORM # 19011

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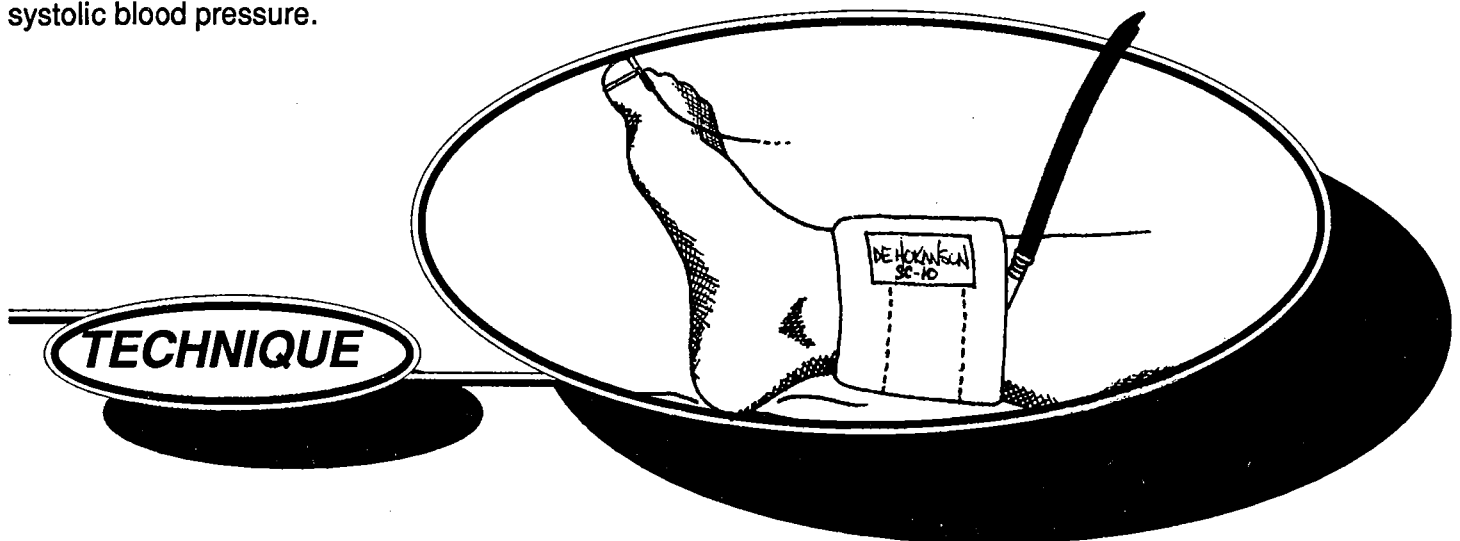
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In cases where it is difficult or impossible to use a Doppler to determine systolic blood pressure, a plethysmograph can determine when blood flow returns with deflation of an arterial occlusive cuff. Since blood is a non-compressible fluid, the flow sensor can be placed anywhere distal to the pressure cuff for the detection of the return of systolic pressure with no decrease in accuracy. For instance, a strain gauge on the toe can be used to detect blood pressure measured at the high thigh. Plethysmographic detection of blood flow is most often used in the leg, arm, digits and penis.

Strain gauge plethysmography is the most sensitive to the return of blood flow. The first pulse that causes flow past the arterial occlusive cuff will make the limb or digit expand and change the length of the strain gauge. This is immediately detected as a volume change by the plethysmograph.

Photoplethysmography is also useful in detection of blood flow, especially when strain gauges are not applicable, on diseased or pressure sensitive digits, and on the penis. The photo transducer detects changes in red blood cell perfusion at cutaneous levels of the skin, and can therefore be used to monitor the return of systolic flow.

Pneumo plethysmography is also a sensitive method for detecting the return of blood flow in measuring systolic blood pressure.



1. Apply an appropriately sized cuff at the site where you want to determine systolic pressure.
2. Attach the strain gauge, phototransducer or pneumo cuff on the toe, the finger, or penis. Connect the strain gauge, phototransducer or cuff to the plethysmograph and select the AC mode.
3. Adjust the range on the plethysmograph to provide a waveform large enough to be easily detected (1-3 cm deflection).
4. Balance the plethysmograph so that the waveform is near the center of the plethysmograph readout or in the middle of the chart recorder.
5. Inflate the cuff above systolic pressure and note the cessation of waveforms on the plethysmograph.
6. Re-balance the plethysmograph so that the baseline is near the bottom of the meter and/or chart recorder.
7. Slowly deflate the cuff. The return of pulsations or waveforms on the plethysmograph or chart recorder occurs when the cuff pressure reaches the systolic blood pressure.

## References

- Nix, M. Lee and Robert Barnes, 'Diagnostic Techniques' Medical College of Virginia, 1980.  
Nix, M. Lee, Personal Communication.



# ANKLE / BRACHIAL INDEX SEGMENTAL PRESSURES

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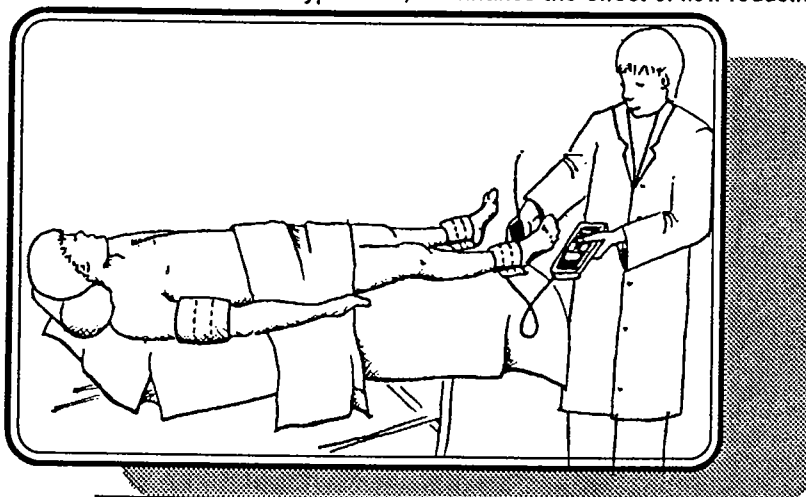
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## ANKLE/BRACHIAL INDEX

Comparing systolic blood pressure in the arm to the systolic pressure in the ankle is one of the easiest and most effective tests for detecting arterial disease in the lower limbs. In a normal person, resting ankle blood pressure is slightly greater than brachial blood pressure, due to hemodynamic and gravitational effects. Systolic pressure is more sensitive to arterial disease than mean pressure or diastolic pressure.\* The pressure loss caused by a stenosis can be enhanced by increasing blood flow, either by exercise or by inducing reactive hyperemia with an occlusive cuff.

## TECHNIQUE

1. Position the patient supine on the examination table.
2. Apply cuffs on both arms above the elbow and on both ankles above the malleolus.
3. Determine arm systolic blood pressure first, by listening with a Doppler at the brachial or radial artery. This pressure will become the denominator in the Ankle/Brachial Index.
4. Next, determine blood pressure at the ankle. Monitor either the dorsalis pedis or the posterior tibial artery, whichever gives the strongest signal. This number is the numerator in the Ankle/Brachial Index.
5. Compute the ABI by dividing ankle systolic pressure by the highest arm systolic pressure and compare the value to the chart below.
6. The test can be repeated after exercise or reactive hyperemia, to enhance the effect of flow reductions. \*\*



## ANKLE/BRACHIAL INDEX VALUES AT REST

|                  |                           |
|------------------|---------------------------|
| GREATER THAN 1.0 | NORMAL                    |
| 1.1 TO 0.4       | INTERMITTENT CLAUDICATION |
| 0.4 TO 0.3       | ISCHEMIC REST PAIN        |

**NOTE: LEG PRESSURES SHOULD BE SLIGHTLY HIGHER THAN ARM BLOOD PRESSURE IN NORMAL PATIENTS. IF ANKLE PRESSURE IS 110% OR MORE OF ARM BLOOD PRESSURE, IT IS NOT NECESSARY TO CONTINUE WITH MORE PROXIMAL MEASUREMENTS. IF ANKLE PRESSURE IS NOT 110% OF ARM PRESSURE, A SEGMENTAL PRESSURE EXAMINATION MAY BE PERFORMED TO DETECT THE SITES OF OBSTRUCTIONS. IN DIABETIC PATIENTS ABI'S ARE INVALID.**

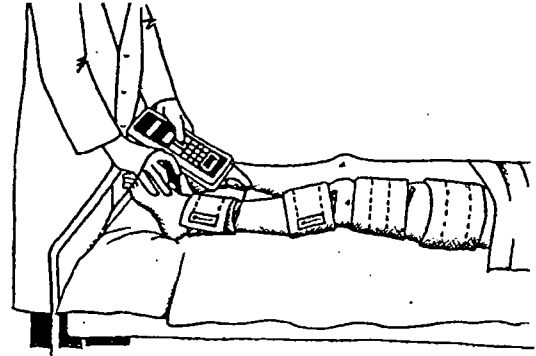
## SEGMENTAL PRESSURES

Arterial disease in the lower limbs can be localized by measuring blood pressure gradients over different segments of the leg. Significant changes in arterial systolic pressure between adjacent sites and /or similar contralateral sites indicate flow disturbance caused by reduced vessel cross sectional area. In the case of multi-segment disease this test can help determine which disease site is most significant.

The effects of stenoses can be emphasized by increasing blood flow, either by exercise testing or by inducing reactive hyperemia with an occlusive cuff.

### TECHNIQUE

1. After an ANKLE/BRACHIAL INDEX examination has been done, apply cuffs to the following sites: proximal thigh, distal thigh, just above the knee (if you have not done an index apply a cuff to the ankle).\*
2. Use a continuous wave Doppler to locate the ankle arteries, and monitor the artery that gives the clearest signal.
3. Inflate the ankle cuff above systolic pressure, then slowly deflate and record the pressure at which systolic flow returns.
4. Inflate the below knee cuff and repeat the process.
5. Continue up the leg to the above knee and high thigh cuffs, repeating same process.



### STRESS TESTING

Increasing flow rates will enhance the effects of stenosis. An exercise test originated by Strandness involves walking a treadmill at 2 mph on a 12% grade. Walking continues for 5 minutes or until the patient claudicates. Record the time walked and measure ankle pressure immediately after exercise. If the patient is unable to walk, induce hyperemia by applying a large blood pressure cuff on the proximal thigh; inflate it to 50 mmHg above systolic pressure and leave it inflated for 3 minutes. Then quickly deflate the cuff and determine ankle pressure immediately.\*\*\*

Normally, with exercise, systolic pressures will increase both in the arm and in the legs. In diseased states, the systolic pressure will drop. How much the pressure drops and how long it stays reduced is indicative of the severity of the disease. Normal patients will drop their pressure immediately after cuff release in the reactive hyperemia test. They will, however return to 90% of their pre-occlusive pressure within one minute. Patients with arterial occlusive disease will take a longer time to return to the pre-occlusion levels.

### INTERPRETATION

*Cuff artifact accounts for higher pressures measured in the upper leg. It is important to compare similar sites on both legs and to take in account the size of the leg in judging the amount of artifact. Contralateral sites should not vary by more than 15 mm Hg on normal individuals. The following chart shows typical values used in interpretation when all pressures are measured with a 10 cm straight segmental cuff. High thigh and above knee pressures will be slightly lower if 12 cm cuffs are used.*

|                                             |                                |                                               |
|---------------------------------------------|--------------------------------|-----------------------------------------------|
| <b>BELOW KNEE MINUS ANKLE PRESSURE</b>      | 0 TO 20 mm                     | Normal                                        |
|                                             | GREATER THAN 20 mm             | Suspicious of disease in calf                 |
| <b>ABOVE KNEE MINUS BELOW KNEE PRESSURE</b> | 0 TO 20 mm                     | Normal                                        |
|                                             | GREATER THAN 20 mm             | Suspicious of disease at knee                 |
| <b>THIGH MINUS ABOVE KNEE PRESSURE</b>      | 0 TO 30 mm                     | Normal                                        |
|                                             | GREATER THAN 30 mm             | Suspicious of disease in thigh                |
| <b>THIGH PRESSURE</b>                       | 30 mm or more greater than arm | Normal                                        |
| (see reference 3)                           | Less than 30 mm or arm         | Suspicious of disease above inguinal ligament |

Typically either SC-10 or SC-12 straight segmental cuffs are used (10 cm x 41 cm and 12 cm x 41 cm bladder size, respectively). Some labs use all SC-10's and some use all SC-12's. Consistency is important and if a routine has not been established, we recommend SC-12's above the knee and SC-10's below. Because of the girth of the thigh, the pressures in the thigh cuffs will be artificially elevated compared to true systolic pressure, even on normal patients. Remember to take this into account when comparing adjacent sites on the leg.

#### References

- \*R. E. Zierler, presented at Oregon Heart Center Conference on Non-Invasive Diagnosis of Vascular Disorders, May 9, 1986, Eugene, Oregon. Values given are minimums for symptoms described.
- \*\*Thiele, Brian L, 'Role of Pressure Measurements-Direct and Indirect' in Noninvasive Diagnostic Methods, Continuing Medical Education Symposium, University of Washington School of Medicine, November 30, 1981.
- \*\*\*Strandness, D.E. Jr., Personal communication

# DIGIT BLOOD PRESSURE

**Hokanson**

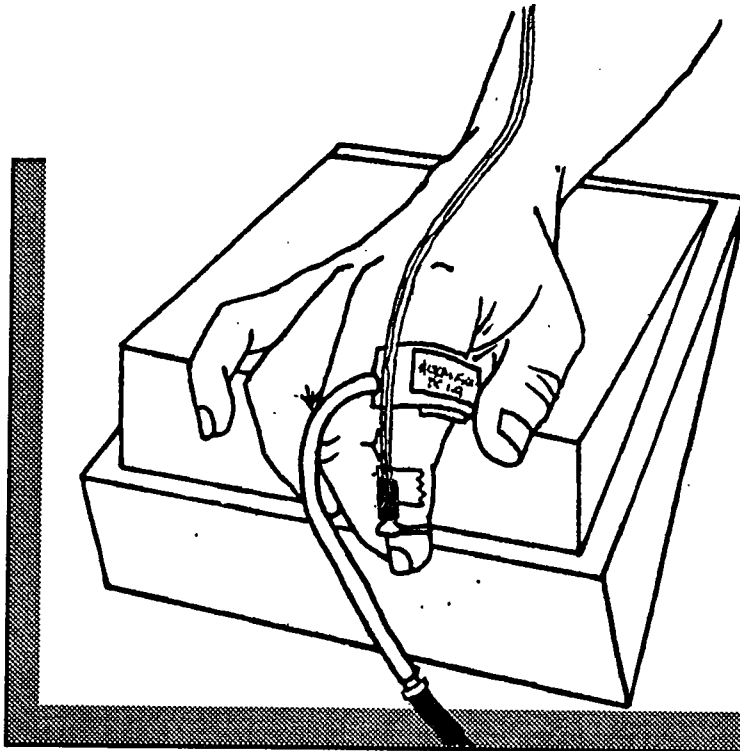
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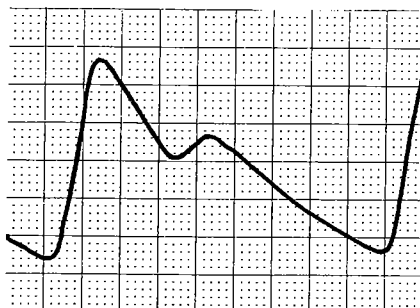
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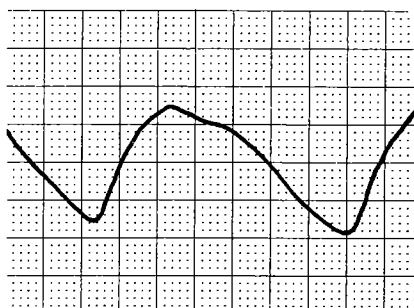
Blood pressure in digits is easily measured using strain gauge, photo, or pneumo plethysmography. Digit pressures are used to detect arterial obstruction, and can be related to brachial blood pressure or ankle blood pressure as a pressure index. They are also used to determine the probability of healing following amputation. Strain gauge, pneumo or photo plethysmography may be used to measure digit pressures, depending on the preference of the user.

Digit waveforms obtained by plethysmography are important. Examination on the waveform can show obstruction of the palmar arch as digital arteries as well as cold sensitivity.

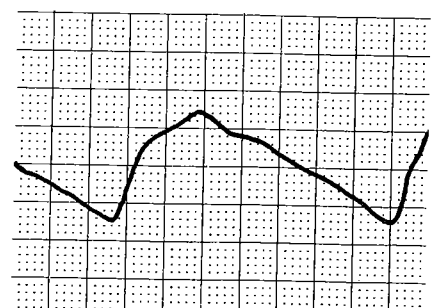
**NORMAL**



**OBSTRUCTIVE**



**PEAKED**



## TECHNIQUE

**Read the first three instructions, then proceed to the modality that you are using .**

- 1) Have the patient at rest in a supine position.
- 2) Support the hand or foot so that arterial circulation is not restricted by posture. The digit to be tested should be at approximately heart level.
- 3) Select an appropriate size pressure cuff for the digit to be examined and wrap it around the proximal part of the toe or finger. Cuff width should equal or exceed the diameter of the digit.

### **Photo Plethysmography (PPG)**

Use the AC function on the plethysmograph for digit PPG. Photoplethysmographs are not quantitative, but are useful for qualitative pulse waveform recordings. Attach the phototransducer to the distal pad of the digit with tape. Select a sensitivity setting that gives pulses of approximately 5 mm on the chart recorder prior to inflation of the cuff. Applying a thin layer of ultrasound gel to the face of the transducer can enhance coupling and light transmission. Inflate the cuff above systolic pressure. Start the recorder on slow and re-balance to ensure the tracing is visible on the chart paper. Slowly deflate the cuff. Systolic pressure is indicated by the return of pulsations when using PPG in AC mode, and/or by a sharp rise in the recording when using PPG in DC mode.

### **Pneumo Plethysmography**

Use the AC or DC mode of the plethysmograph. Apply an appropriate digit cuff to the distal part of the digit and connect it to the hose from the pneumo plethysmograph. This will be the sensing cuff which indicates the return of flow when pressure is lowered in the pressure cuff. Inflate the sensing cuff to 40 mmHg and close the valve to the cuff inflator. Select a range setting that gives pulses of approximately 5 mm on the chart recorder prior to inflation of the pressure cuff. Inflate the pressure cuff to above systolic pressure. Start the chart recorder on SLOW and rebalance the plethysmograph to ensure that the tracing is on the chart. Slowly deflate the pressure cuff and note the systolic pressure when pulsations appear (in AC mode) or when the baseline rises sharply (in DC mode).

### **Strain Gauge Plethysmography (SPG)**

Use either AC or DC for digit SPG. AC will help keep the wave tracing centered on the recorder but gives only qualitative information on the shape of the waveform. DC wave tracings will drift with respiration but the waveform gives quantitative data on absolute volume change. Attach an appropriately sized strain gauge (about 0.5 cm smaller than digit circumference) around the digit. Make certain the junction or end of the strain gauge is past the nail, and take care not to roll it on or pull the rubber tubing at a sharp angle to the copper electrodes. Tape the lead wire to the digit at a point close to the gauge so it won't move when you inflate the cuff. Balance the machine and select a sensitivity setting that gives pulses of approximately 5 mm on the chart recorder prior to inflation of the cuff. Inflate the occluding cuff above systolic pressure. Start the recorder on slow and re-balance to ensure the tracing is visible on the chart paper. Slowly deflate the cuff. Systolic pressure is indicated by the return of pulsations when using SPG in AC mode, and/or by a sharp rise in the recording when using SPG in DC mode.

**Normal values for digits are somewhat below resting brachial pressure.**

|                       |       |                    |
|-----------------------|-------|--------------------|
| Finger/Brachial Index | _____ | 0.8 or more        |
| Wrist-Finger Gradient | _____ | less than 20 mm Hg |
| Toe/Brachial Index    | _____ | 0.8 or more        |
| Ankle-Toe Gradient    | _____ | less than 20 mm Hg |

#### **References**

Lamb, Sarah I., Joy Anderson, Kenneth Selfert and William Blackshear, 'The Optimum Method of Toe Pressure Measurement' BRUIT, Vol 7, Dec. 1983  
Nix, M. Lee and Robert Barnes, 'Diagnostic Techniques' Medical College of Virginia, 1980

# THORACIC OUTLET SYNDROME

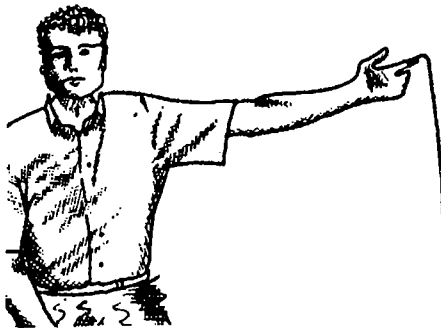
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A.N. FORM # 19012

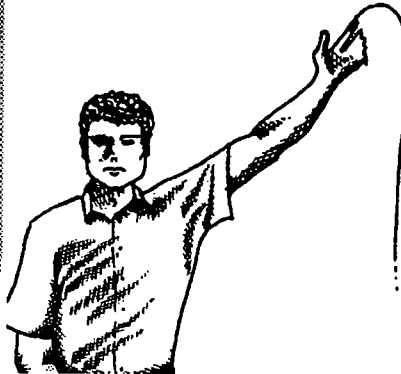
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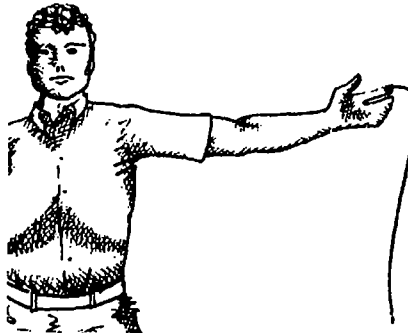
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*Position A*



*Position B*



*Position C*



*Position D*



*Position E*

Strain gauge, pneumo, photo plethysmography or Continuous wave Doppler is used to evaluate arm ischemia related to the thoracic outlet syndrome. Most symptoms are due to compression of the lower roots of the brachial plexus, although vascular complications can occur in the presence of a cervical rib. The test for thoracic outlet syndrome involves monitoring blood flow in the lower arm or hand while performing maneuvers designed to produce the symptoms. Since the disease is often bilateral, both limbs should be tested.

## TECHNIQUE

Doppler velocity signals can be monitored at the radial artery for quantitative assessment, but it is easier on the examiner and the patient to attach a strain gauge, pneumo sensing cuff or phototransducer to the pad of a digit and monitor the change of the volume pulse wave on a plethysmograph and chart recorder.

1. Position the patient sitting erect on a chair or the side of the examination table. Monitor blood flow in one of the following ways:

### USING A DOPPLER:

Obtain a suitable Doppler waveform at the brachial artery and establish artery and establish baseline velocity recordings. These must be monitored at the same site throughout the test.

### USING A PHOTO TRANSDUCER:

Attach to the distal pad of the index finger of the side being tested.

### USING A PNEUMO CUFF:

Attach an appropriately sized cuff to the distal finger and inflate this sensing cuff to 40 mmHg.

### USING A MERCURY STRAIN GAUGE:

Attach a strain gauge approximately 0.5 cm smaller than the distal finger. Tape the lead wire to the finger in a way to prevent movement of the strain gauge without restricting flow to the finger.

2. Place the patient's hands, palm up, in his lap.
3. When doing the examination with plethysmography, use the AC mode, balance the plethysmograph and obtain a suitably sized waveform with the patient at rest to compare later as a reference.

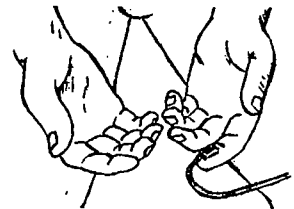
**Position A:** Elevate the arm to a 90 degree angle, straight out to the side, and mark the chart recording to indicate this position.

**Position B:** Elevate the arm to 120 degrees and repeat the recording.

**Position C:** Lower the arm back down to 90 degrees and have patient assume a military attention position with the shoulders down and back.

**Position D:** Have the patient turn his head toward the affected arm.

**Position E:** Have the patient turn his head away from the affected arm.



## Interpretation

Pulse amplitude should decrease as the arm is elevated. Arterial compression is indicated if the amplitude goes flat in any of the positions. Because approximately 25% of the population will exhibit arterial compression in one or another of the positions, diagnosis and therapy should include data on symptoms, neurology, patient history and physical examination. Also, since anatomic aberrancies are frequently symmetrical, bilateral studies should always be performed.

### References

Nix, M. Lee and Robert Barnes, 'Diagnostic Techniques' Medical College of Virginia, 1980.  
'Noninvasive Diagnostic Techniques In Vascular Disease', 3d Edition, Eugene Bernstein, editor, pp 568-569, C.V. Mosby 1985.

## ELECTRICAL LEAKAGE AND HIPOT TEST

INSTRUMENT: \_\_\_\_\_

SERIAL NUMBER: \_\_\_\_\_

### LEAKAGE TEST:

| MODE                                     | GROUND | POWER ON |         | POWER OFF |         | CURRENT<br>LIMIT (uA) |
|------------------------------------------|--------|----------|---------|-----------|---------|-----------------------|
|                                          |        | normal   | reverse | normal    | reverse |                       |
| EXPOSED<br>CHASSIS<br>METAL TO<br>GROUND | OPEN   |          |         |           |         | 100 uA AC             |
|                                          | INTACT |          |         |           |         | 10 uA AC              |
| DOPPLER<br>CONN. RING<br>TO GROUND       | OPEN   |          |         |           |         | 0.0 uA DC             |
|                                          | INTACT |          |         |           |         | 100 uA DC             |

\_\_\_\_\_ PASSED HIPOT TEST: 60 SECONDS AT 1500 VAC

\_\_\_\_\_ PASSED GROUND IMPEDANCE TEST: < .1  $\Omega$  AT 25 AMPS FOR 10 SECONDS

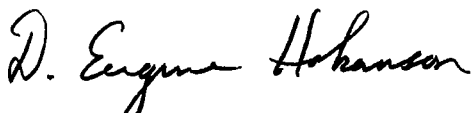
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**EC Declaration of Conformity**

|                                                                               |                                                                                                                                                                                                              |
|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Manufacturer                                                                  | D. E. Hokanson, Inc.<br>12840 NE 21 <sup>st</sup> Place<br>Bellevue, WA 98005, USA<br><br>Tel 425 882 1689      Fax 425 881 1636                                                                             |
| Authorized Representative in EC                                               | Hokanson UK<br>Waldeck House, Waldeck Road<br>Maidenhead, Berkshire<br>SL6 8BR England                                                                                                                       |
| Details of Electrical Equipment<br>Model number:                              | Procord Vascular Diagnostic System, MD35                                                                                                                                                                     |
| Classification of Device (Annex IX)                                           | Ila                                                                                                                                                                                                          |
| Description                                                                   | Line or internally powered Class 1B<br>equipment<br>230VAC, 0.12 Amps                                                                                                                                        |
| Directives this equipment complies with                                       | Medical Devices Directive, 93/42/EEC                                                                                                                                                                         |
| Harmonized Standards applied in order to<br>verify compliance with Directives | EN60601-1, Medical Electrical Equipment –<br>Part 1: General Requirements for Safety.<br><br>EN 55011:1991 Radiated and Conducted<br>Emissions<br><br>EN60601-1-2 RF Immunity and Electrostatic<br>Discharge |
| Technical Construction File                                                   | Not applicable                                                                                                                                                                                               |
| Year in which CE Mark was affixed                                             | 1998                                                                                                                                                                                                         |
| Date of Issue                                                                 | April 15, 1998                                                                                                                                                                                               |

  
D. Eugene Hokanson, President

Bellevue, WA 98005, USA